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Parts I and II of the students' guide to the three-year integrated biology, chemistry, and physics course being prepared by the Portland Project Committee are contained in this guide. A committee reviewed and selected material developed by the national course improvement groups--Physical Science Study Committee, Chemical Bond Approach, Chemical Education Materials Study, Biological Science Curriculum Study and Introductory Physical Science--and added material written especially for the project. This material was fitted into a previously prepared course outline which endeavored to match students' abilities, interests, and maturity level with the level of sophistication of the concepts. This course was to be taught for the first time in eight Oregon schools in the 1967-68 academic year. This guide contains Part I, "Perception and Quantification" and Part II, "Properties of Matter." These themes are developed through student-centered activities. A table relates the student activity to the most pertinent text reference or suitable film. (GR)

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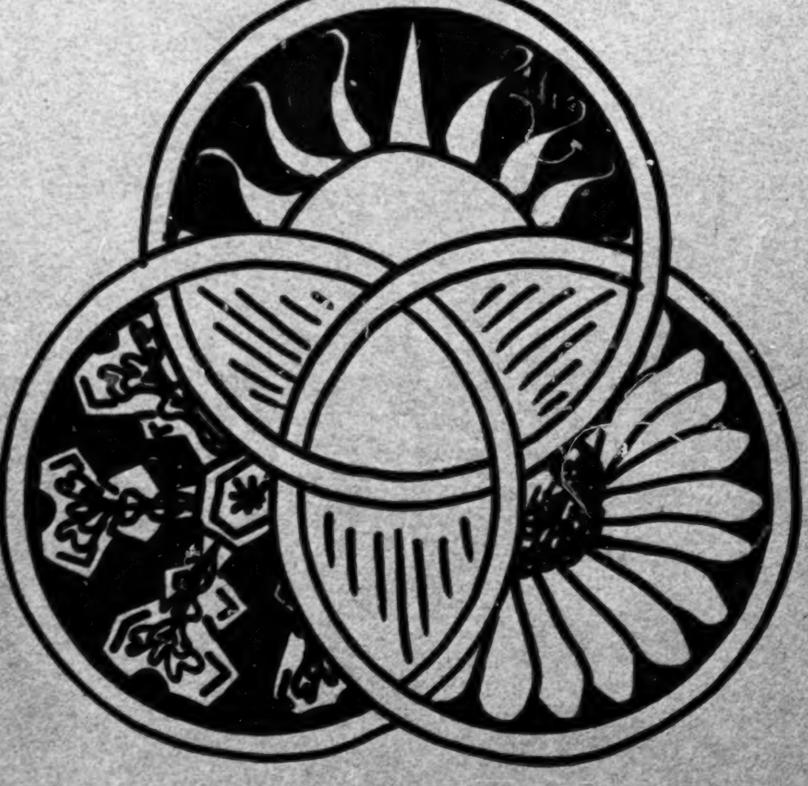
58
124

PARTS I & II

BIOLOGY--
CHEMISTRY--
PHYSICS

A THREE-YEAR SEQUENCE



STUDENTS' GUIDE

PILOT SCHOOL EDITION

prepared by
THE PORTLAND PROJECT COMMITTEE

under a grant from
THE NATIONAL SCIENCE FOUNDATION

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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STUDENT'S GUIDE FOR

BIOLOGY-CHEMISTRY-PHYSICS

A THREE-YEAR SEQUENCE

PILOT SCHOOL EDITION
1967

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Dedication

This volume is dedicated to the memory of Vernon Cheldelin under whose guidance and leadership integration of the sciences for Oregon secondary school youth was begun in 1963.

- Introduction -

The Portland Project was initiated in the fall of 1962 when two secondary school teachers, one with background in CBA chemistry, the other having responsibility for PSSC physics, began to note and discuss the redundancy in their respective courses. Why should students be subjected to this repetition and fragmented representation of the physical sciences? they asked. Their persistence in asking these questions resulted in the formation of a Steering Committee whose function was to pursue the problem further and perhaps enlist the support of a funding organization to permit its exploration in depth. Under the able and devoted leadership of Vernon Cheldelin, Dean of the School of Science at Oregon State University (deceased), two proposals prepared for support by the National Science Foundation were funded in the summers of 1963 and 1964.

Since inception of the Portland Project, twenty-two scientists and teachers have devoted various quantities of time as writers, consultants, pilot teachers and evaluators, with the aim of ascertaining the feasibility and efficiency of the integration of chemistry and physics. Concurrently and subsequently, other groups in other parts of the country have carried on studies that are approximately parallel to this one.[1] Though the conceptual development and points of emphasis differ, the various groups are satisfied that integration of science courses is not only feasible but highly desirable.

---

[1] Federation for Unified Science (FUSE) was recently organized to act as a clearinghouse of information on integrated science courses. Victor Showalter at Ohio State University is the chariman of this committee.

Empirical studies conducted by Dr. Michael Fiasca of the Education and Science Staffs of Portland State College reveal that subject matter achievement in chemistry and physics and critical thinking abilities are enhanced among students who studied the integrated courses over those who study the separate disciplines of chemistry and physics. It should be emphasized that though these differences were apparent, it could not be demonstrated that they were statistically significant.[2] A concomitant result showed that enrollments in the two-year integrated courses were dramatically greater than in the separate courses.

A survey completed April 15, 1967, showed that there are now forty-four schools in twenty states using the Portland Project integrated courses.[3]

Mounting evidence in the literature from prominent persons working in science education strongly supported this mode of organization. Men like Dr. Jerrold R. Zacharias, the prime instigator of the PSSC physics program, exemplified the changing attitude:

> The division of science at the secondary school level, into biology, chemistry, and physics is both unreasonable and uneconomical.

---

[2] Detailed results of this study may be obtained by writing to Dr. Fiasca at Portland State College.

[3] Detailed enrollment figures and addresses of people who are using the Portland Project courses may also be obtained from Dr. Fiasca.

> Ideally, a three-year course that covered all three disciplines would be far more suitable than a sequence of courses which pretends to treat them as distinct. Today such a three-year course would be difficult to fit into the educational system, but much of this difficulty might be overcome at once if such a course existed, and it might well be that present tendencies in education would soon overcome the rest.
>
> In any case, a greater coordination of the three subjects is possible even within the existing framework. It is understandable that the groups which developed the existing programs, each of which faced great problems of its own as it worked toward its goals, were reluctant to embark on the larger task of giving coherence to the sum of their efforts. With the programs now complete or approaching completion, it may be that the time has arrived for this necessary step.[4]

Stimulated by the apparent success of their original work towards this kind of integrated course, persons close to the Portland Project began to discuss extension of their work to include biology with chemistry and physics in a three-year sequence. A third proposal was prepared in 1966 and granted support by the National Science Foundation this year. Dr. Arthur Scott, member of the Chemistry Department at Reed College who has had deep interest in the Portland Project since its inception, graciously offered his talents, energy and time to carry on the project after Dean Cheldelin's death.

A writing conference was conducted on the Portland State College campus during the summer of 1967 to develop materials such as teacher and student guides. Eight local pilot schools have already committed approximately five hundred students and twelve pilot teachers for testing and evaluation. Dr. Donald Stotler, Supervisor of Science for the Portland School District, has had an active part in this and other phases of this project.

---

[4] From page 52 of Innovation and Experiment in Education, a Progress Report of the panel on Educational Research and Development to the U.S. Commisioner of Education, the Director of the National Science Foundation, and the Special Assistant to the President for Science and Technology, March, 1964.

Twnety-six persons whose functions were writing, consulting, analysis and editing met on the Portland State campus beginning June 14, 1967, to begin preliminary work on the integrated course. Their first task was to formulate an outline that displayed logical content development utilizing concepts out of biology, chemistry and physics. Particular attention was paid to matching students' abilities, interests and maturity level with the sophistication of concepts as nearly as this was possible to do. Then the committee perused material developed by the national curriculum groups--PSSC, CBA, CHEMS, BSCS and IPS--in search of material to implement the outline they constructed previously. In the absence of appropriate materials, major and minor writing projects were initiated.

It was anticipated that the conclusion of the summer should see assembly of an outline for the three-year course, production of student and teacher manuals for pilot schools and perhaps a few for distribution to interested persons, and the design and implementation of an evaluation study that sought to assess changes in student achievement in the separate academic disciplines, cross disciplinary carry-over, critical thinking abilities and science attitudes.

The Working Committee

The committee is composed of both college and high school science teachers with training and teaching experience in the separate disciplines of biology, chemistry and physics and several cross disciplines.

Carl Bachhuber--Physics
Portland State College
Portland, Oregon

Renee Bergman--Physical Science
Roosevelt High School
Portland, Oregon

Louis Bixby--Chemistry
St. Louis Country Day School
St. Louis, Missouri

Howard Browning--Chemistry & Physics
Benson Polytechnic School
Portland, Oregon

Steven Dimeo--Editor
University of Oregon
Eugene, Oregon

Karl Dittmer--Co-Director, Biochemistry
Portland State College
Portland, Oregon

Arleigh Dodson--Chemistry
Lewis and Clark College
Portland, Oregon

Michael Fiasca--Co-Director, Physics
Portland State College
Portland, Oregon

Edward Fuller--Chemistry
Beloit College
Beloit, Wisconsin

Curtis D. Guthrie--Chemistry
Wilson High School
Portland, Oregon

Glen Hampshire--Chemistry & Physics
Jefferson High School
Portland, Oregon

Lois Helton--Biology & Chemistry
Beaverton High School
Beaverton, Oregon

George Ingebo--Director of Research
Portland School District
Portland, Oregon

Henry Kilmer--Biology & Chemistry
Rex Putnam High School
Milwaukie, Oregon

Helen Koopman--Physical Science
Jefferson High School
Portland, Oregon

Alfred Levinson--Chemistry
Portland State College
Portland, Oregon

David Malcolm--Biology
Portland State College
Portland, Oregon

Edmund D. McCollough--Chemistry
Cleveland High School
Portland, Oregon

Thomas Miles--Biology
Cleveland High School
Portland, Oregon

Leon Pape--Biophysics
California State College at Los Angeles
Los Angeles, California

Arnold Pickar--Physics
Portland State College
Portland, Oregon

David Porter--Physics
Portland Community College
Portland, Oregon

Jack Sadler--Biochemistry
University of Colorado Medical Center
Denver, Colorado

Arthur Scott--Chemistry
Reed College
Portland, Oregon

Joseph Sklenicka--Physics
Franklin High School
Portland, Oregon

Donald Stotler--Supervisor of Science
Portland School District
Portland, Oregon

Harold Wik--Science Coordinator
Beaverton School District 48
Beaverton, Oregon

- Pilot Schools -

The following schools have offered to try the first year of the three-year integrated course during the 1967-68 academic year:

Beaverton High School
Beaverton, Oregon
Lois Helton

Benson Polytechnic School
Portland, Oregon
Howard Browning

Cleveland High School
Portland, Oregon
Edmund D. McCollough
Thomas Miles

Franklin High School
Portland, Oregon
Joseph Sklenicka

Jefferson High School
Portland, Oregon
Glen Hampshire
Helen Koopman

Rex Putnam High School
Milwaukie, Oregon
Henry Kilmer

Roosevelt High School
Portland, Oregon
Renee Bergman
Kenneth Fuller

Wilson High School
Portland, Oregon
Curtis D. Guthrie
Ernest Hohman

- Acknowledgements -

The Portland Project Committee wishes to acknowledge the dedicated efforts of the following people:

Mary Grant	Artist
Alice Eyman	Secretary
Pamela Thompson	Secretary
Barbara Wiegele	Secretary
Neomia Kendrix	Technician

- Three-Year Course Rationale -

In designing a three-year sequential science course, one of the major considerations that should be borne in mind is that the sophomore course must be looked upon as both a terminal science experinece for many students and an introductory course for those seriously interested in science. Therefore, formulation of the sophomore course must be considered together with what follows in the junior-senior courses and yet apart from it. The sophomore course must stand as a coherent entity equipping students with skills and modes of behavior which characterize the working scientist, capturing their interest and enthusiasm for later encounters with science both in formal education and outside the classroom, and impressing upon them knowledge about some of the major generalizations we call science.

Clearly, if the sophomore level course is only nominally successful in each of these three aims, it will serve well as both an introduction to more sophisticated biological, chemical and physical ideas treated in subsequent years as well as a realistic presentation of the three sciences and their epistomologies.

The committee agreed that biological content for the sophomore course should be environmental in its emphasis. This decision was made for the reasons that this kind of knowledge is fundamental to appreciation of the real problems that confront men today--e.g., control of human population; resource conservation; acute, delayed and cumulative effects of food, air and water pollution; and physiological and other biological effects of drugs and narcotics on the human organism. Molecular biology, we believe, is more appropriately placed at the senior level of the integrated sequence where students have developed some facility with ideas from chemistry and physics--e.g., quantitative knowledge about energy, mechanisms of chemical reaction, equilibrium, rate or reaction, the photon and wave nature of light, electrical phenomena and kinetic molecular theory. They should not simply parrot biochemical processes as photosynthesis and cell respiration, but should truly understand many chemical and physical ramifications of these reactions.

Excessive formalism and quantization is avoided in the sophomore course. The committee identified several reasons for this decision. Usually students at this level do not extract essential meaning from such a presentation of information. It can be defended that first encounters with new ideas should proceed from an intuitive, non-quantitative confrontation to one that is more quantitative. Many teachers have recognized and spoken out against teaching and learning methods which substitute equations, formulas and other quantitative representation for first-hand experience, word descriptions, examples and illustrations. This argument is just as valid for students who are very bright and very interested in science as it is for other students. In addition, the mathematics sophistication of sophomores often precludes immersing them too deeply into mathematical arguments as an explanation for natural phenomena.

The three-year sequence is thus calculated to semi-quantitatively introduce students to some of the significant generalizations of science and how these generalizations came to be, then to re-cycle these ideas in the junior and senior years while dressing them up with the language of mathematics. Inspection of the three-year course outline manifests re-cycling a number of topics such as properties of matter, energy, certain biological concepts and the processes and tools of science.

The typical science experiences of most secondary school boys and girls consists of one or two years devoted to general science and biology. Rarely do they study physics and chemistry. A significant advantage to the course of study embodied in this manual is that most students are given this opportunity and, what is more, on a level of rigor that they can take. Students who terminate at the conclusion of the sophomore year have had significant exposure to the structure of biology, chemistry and physics in a way that scholars view these sciences as they are presented in BSCS, IPS, CBA, CHEMS and PSSC. Bright students who may not have elected science beyond the sophomore level because of a lack of interest in biology may be challenged by the chemistry and/or physics portions of the course and elect either the second and third year of the integrated sequence or other junior-senior level science courses.

It was with the consideration of these problems and goals that the general course outline for the sophomore level was finally derived. It consists of four main parts:

(1) Perception and Measurement

(2) Properties of Matter

(3) Energy in Non-Living and Living Systems

(4) Ecological Systems

There is a rationale behind this method of organization. The study of this year of science begins with the perceiver, moves on to the perceived and ends with the interaction of both the perceiver and the perceived. The sophomore first gains a better awareness of the nature of his perception and senses--the faculties that let him realize the world about him. With an increased understanding of these perceptual abilities, he can turn to the environment, then relate himself to his environment. He will find that his perception is limited and often needs to call on technological and conceptual magnification, but that even these have their limitations.

The committee deliberately included more material than can be learned and taught in the first year of the sequence. Students coming with diverse science experiences should be given some freedom to elect where emphasis should be placed. Teachers also bring to the classroom a variety of interests and backgrounds. Together with students they should plan topic selection and emphasis after due consideration to factors mentioned above.

This sequence is certainly only a beginning to a variety of such efforts that will surely follow. Others will take up the challenge and find, as we have, that there are innumerable, reasonable approaches to the problem of science integration.

- Three-Year Course Outline -

TOPIC	REFERENCE
First Year	
I. Perception and Quantification	
A. Sensing and Perceiving	PP*
B. Measurement, Distribution, Organization and Communication	PP
II. Properties of Matter	
A. The Conservation of Mass	IPS and PP
B. Characteristic Properties	IPS and PP
C. Solubility and Solvents	IPS and PP
D. The Separation of Substances	IPS and PP
E. Compounds and Elements	IPS and PP
III. Energy and Work	
A. Temperature, Calories and Keeping Track of Them	PP
B. Heat and Chaos	PP
C. Heat and Energy Conversions	PP
D. The Work-Energy Conversion	PP
E. Trends in Nature	PP
IV. Ecology	
A. Energy Transfer within Communities	PP and BSCS
B. The Variety of Living Things	PP and BSCS
C. Descent with Modification	PP and BSCS

*PP designation signifies materials produced by the Portland Project.

TOPIC	REFERENCE
D. Reproduction	PP and BSCS
E. Development	PP and BSCS
F. The Integrated Organism and Behavior	PP and BSCS
G. Populations	PP and BSCS
H. Societies	PP and BSCS
I. Communities	PP and BSCS

Second Year

TOPIC	REFERENCE
I. Functions	PSSC
II. Kinematics	PSSC
III. Dynamics	
A. Newton's Laws	PSSC
B. Motion on the Earth	PSSC
C. Universal Gravitation	PSSC
D. Momentum	PSSC
E. Work and Kinetic Energy	PSSC
F. Potential Energy	PSSC
IV. Heat and Energy Effects	
A. Heat and Mechanical Energy	PSSC
B. Heat and Chemical Reactions	PP (to be written)
C. Kinetic Molecular Theory	PP (to be written)
D. Energetics of the Earth and Sun	PP (to be written)
E. Climatology	PP (to be written)

TOPIC	REFERENCE
V. Chemical and Biochemical Reactions	
A. Chemical Reactions and the Mole	CHEM
B. Condensed Phases	CHEM
C. The Periodic Table	CHEM
D. Rates of Chemical Reactions in Biological Systems	PP (to be written)
E. Equilibrium	PP (to be written)
F. Solubility Equilibria in Biological Systems	PP (to be written)
G. Acids and Bases in Biological Systems	PP (to be written)
H. Oxidation and Reduction in Biological Systems	PP (to be written)
I. Chemical Calculations	PP (to be written)
J. Organic Chemistry	CHEM
K. Metabolism	PP (to be written)
1. Photosynthesis	
2. Cellular Respiration	
3. Related Metabolic Activities	
Third Year	
I. Structure and Function in Biological Systems	
A. Transport Systems	BSCS
B. Respiratory Systems	BSCS
C. Digestive Systems	BSCS
D. Excretory Systems	BSCS

TOPIC	REFERENCE
E. Regulatory Systems	BSCS
F. Nervous Systems	BSCS
G. Skeletal and Muscular Systems	BSCS
H. Reproductive Systems	PSP (to be written)
II. Structure and Function in Physical Systems	
A. Optical Systems	PSSC
1. Particle Model for Light	
2. Wave Model for Light	
B. Electromagnetic Systems	PSSC
1. Qualitative Facts about Electricity	
2. Coulomb's Law and Elementary Charge	
3. Energy and Motion of Charges in Electric Fields	
4. The Magnetic Field	
5. Electromagnetic Induction and Waves	
C. Atomic and Nuclear Systems	
1. Exploring the Atom	PSSC
2. Photons and Matter Waves	PSSC
3. Quantum Systems	PP
4. The Orbital Model	PP
III. Structure and Function in Chemical Systems	
A. Chemical Bonding	CHEM
B. Molecular Reproduction and Control	PP (to be written)
1. DNA	
2. RNA	
3. Enzymes	
4. The Origin of Life	

Part I:

PERCEPTION AND QUANTIFICATION

Outline: Perception and Quantification

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
I.	Sensing and Perceiving			
I.1		3 days	S.G.	The Turtle
I.2	Optical Illusions		S.G.	
I.3			S.G.	Reversible Figures
I.4			S.G.	Size Illusions
			Film	"Visual Perception" (19 minutes)
I.4a	Metrology (and Optional Questions)		S.G.	
I.5	Using Illusions		S.G.	
*I.6		1 day	S.G.	Demonstration: Light and Color
			Film	"Blind as a Bat" (7 minutes)
I.7			S.G.	Demonstration: Seeing Through Hearing
**I.8	Limitations of Our Senses	16 days	S.G.	
I.9			S.G.	Touch
I.10			S.G.	Taste
I.11			S.G.	Depth Perception
I.12	Reliability and Validity		S.G.	
I.13			S.G.	Peripheral Vision
I.14			S.G.	Response Time of the Eye

I.15			S.G.	Visual Reaction Time
I.16			S.G.	Auditory Reaction Time
I.17		3 days	BSCS (Green)	Ex. 1.4 The Use of the Microscope
I.18			S.G.	Paramecia and Their Speed
*I.19		1 day	S.G.	Demonstration: Size and Weight

---

*Experiments I.6 and I.19 prepare ahead of time.

**Experiments I.8 - I.16 require extensive preparation.

II.	Measurement, Distribution, Organization and Communication			
II.1	Volume	4 days	IPS 2.1	
II.2	Measuring Volume by Displacement of Water		IPS 2.2	
II.3			S.G.	Demonstration: Volume by Water Displacement
II.4	Shortcomings of Volume As a Measure of Matter		IPS 2.3	
II.5	Mass		IPS 2.4	
II.6			IPS 2.5	The Equal-Arm Balance
*II.7			IPS 2.6	The Precision of the Balance
II.8			IPS 2.7	Beads and Grams
II.9	Measuring and Counting	8 days	S.G.	
II.10	Systems and Units of Counting		S.G.	

II.11	Distance, Mass and Time		S.G.	
II.12			S.G.	The Scalene Triangle
II.13	Uncertainty Associated with Measurement		S.G.	
II.14	Uncertainty Associated with the Instrument		S.G.	
II.15	Human Uncertainty		S.G.	
II.16	Uncertainty Due to Changes within the System		S.G.	
II.17	Range of Uncertainty		S.G.	
II.18	Place of Uncertainty		S.G.	
II.19	Rounding Off to the Correct Place		S.G.	
II.20	Propagation of Errors		S.G.	
II.21	Significant Figures		S.G.	
II.22	Adding Significant Figures		S.G.	
II.23	Subtracting Significant Figures		S.G.	
II.24	Multiplying and Dividing Significant Figures		S.G.	
II.25	Scientific Notation		S.G.	
II.26	Back to the Scalene Triangle		S.G.	
II.27		3 days	S.G.	Mass of the Turtle
*II.28			S.G.	Coin Flipping
			PSSC Film	"Random Events" (30 minutes)

*II.29		5 days	S.G.	Classification and Organization
*II.30			S.G.	Classification of Leaves
II.31			S.G.	Oral Communication Chain
II.32			S.G.	Communicating Ideas
II.33	Observing a System as a Scientist		S.G.	
II.34			S.G.	Test: The Turtle

---

* The day before these experiments ask students to bring from home the following:

II,7 (IPS 2.6) 5-10 pennies

II.28 10 coins

II.30 20 leaves (as many different kinds as possible)

Chapter I: Sensing and Perceiving

I.1 - Experiment: THE TURTLE

How good are your powers of observation? Do you have the patience and the know-how that it takes to be a really good observer? In this experiment you will be observing a familiar object--a turtle.

Write a description of the turtle your teacher places before you on the table. Make it as complete and detailed as you can.

When you have completed your individual lists, one person at each table will be assigned the task of itemizing all the different observations made by your table.

I.2 OPTICAL ILLUSIONS

You have noticed the use of your senses in observing and describing a turtle. How reliable are your senses and the observations you make by means of those senses? See Figures I.1, I.2 and I.3.

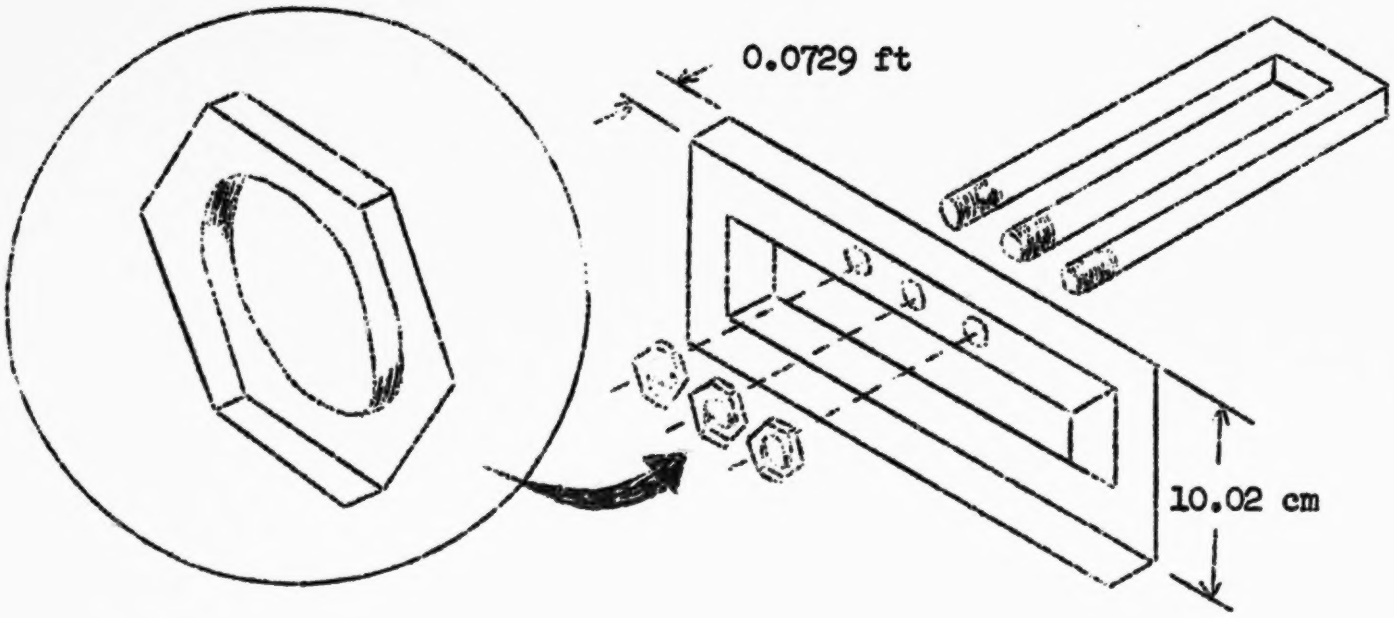


FIG. I.1 - Do you think you can build this? Look again. Observe carefully?

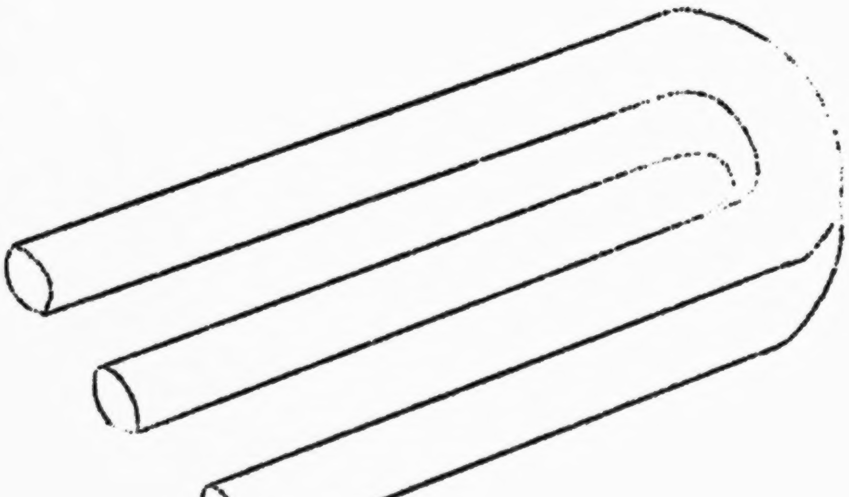


FIG. I.2 - Maybe a round three-pronged figure would be easier.

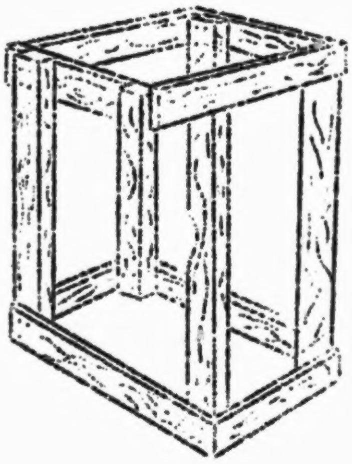


FIG. I.3 - How about a carton to ship it in?

I.3 - Exercise: REVERSIBLE FIGURES

Look at the following pictures and write in your lab book a brief description of what you see. Stare at each figure for several seconds.

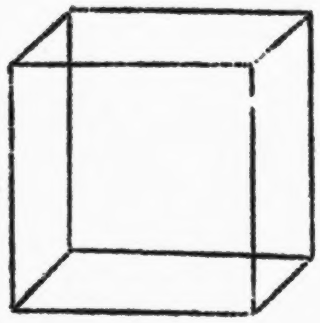


FIG. I.4

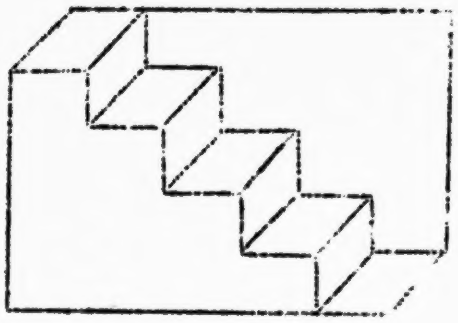


FIG. I.5

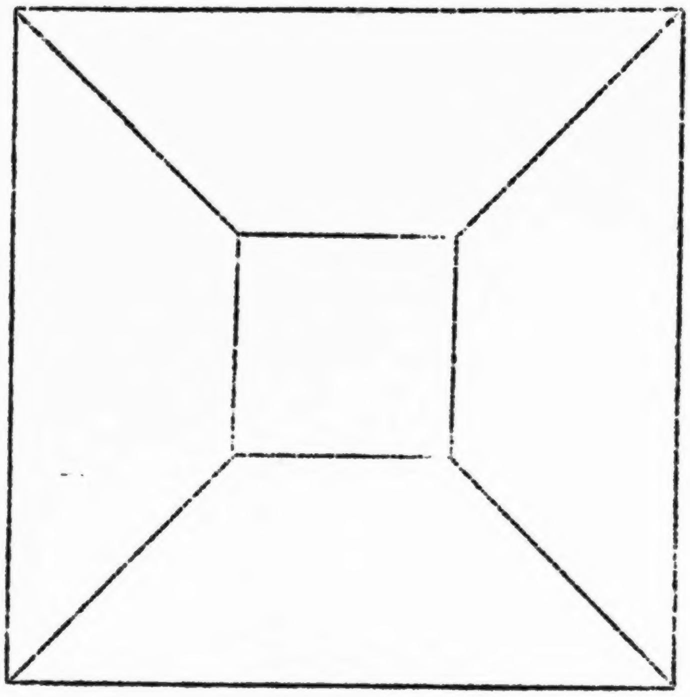


FIG. I.6

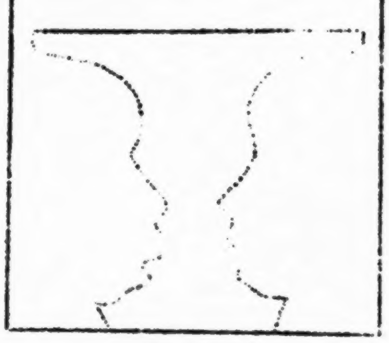


FIG. I.7

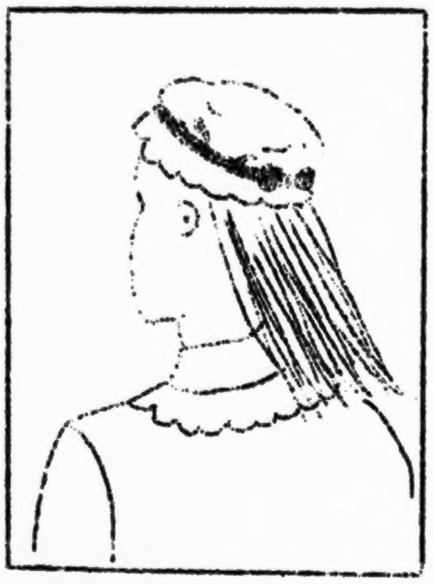


FIG. I.8

Did you all observe the same thing in the same way? Have you any ideas as to why you observed the phenomena that you did?

I.4 - Experiment: SIZE ILLUSION

Look at the following figures and record in your lab book which is larger, A or B? Do not be influenced by what you may know to be the right answer.

Which one do you think looks larger?

Estimate how much larger. (Do not measure.)

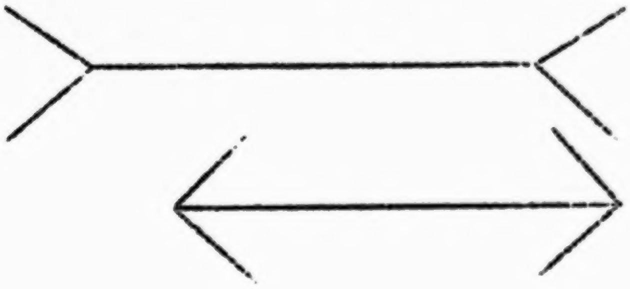


FIG. I.9 - Top one is A, bottom is B.
Which is longer?

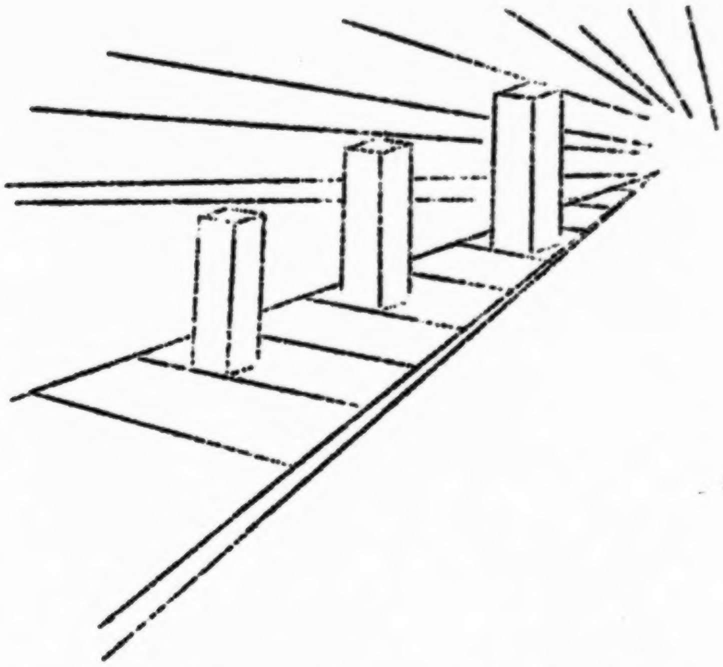


FIG. I.10 - Front post is A, back post is B. Which is taller?

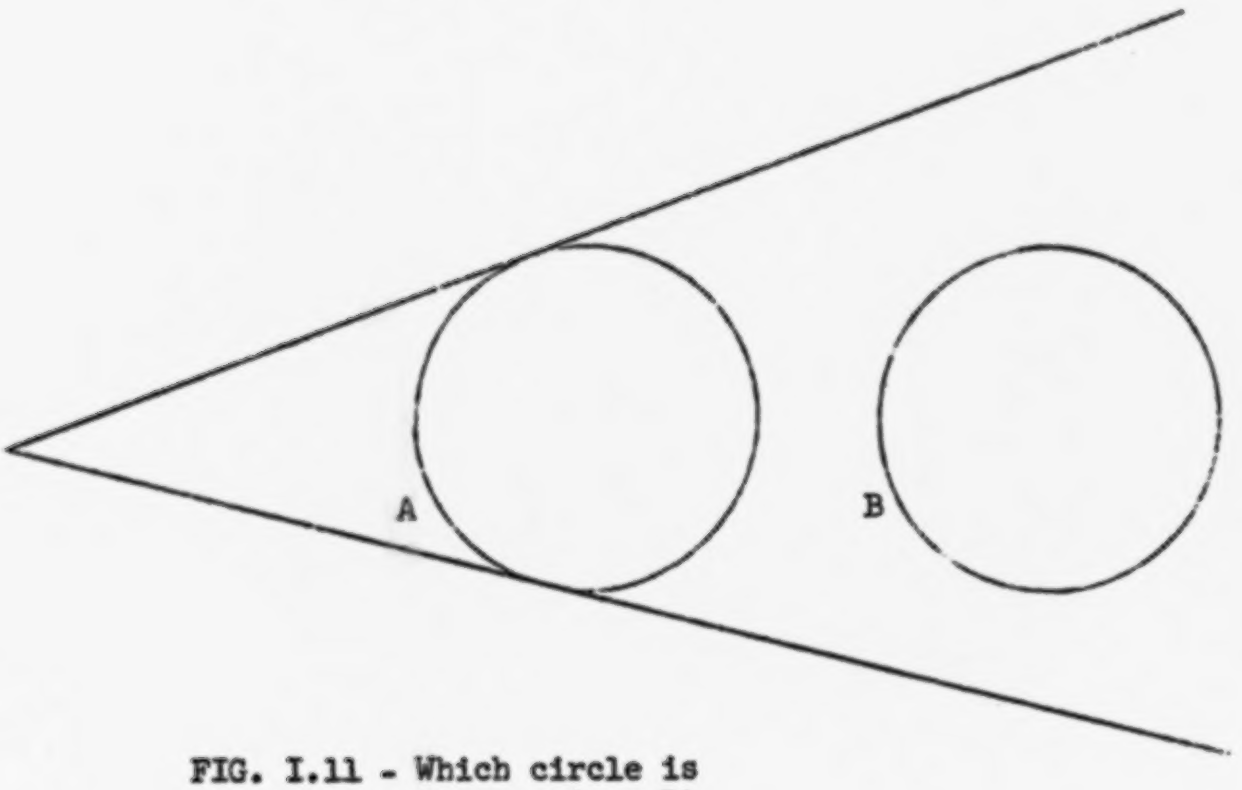


FIG. I.11 - Which circle is larger, A or B?

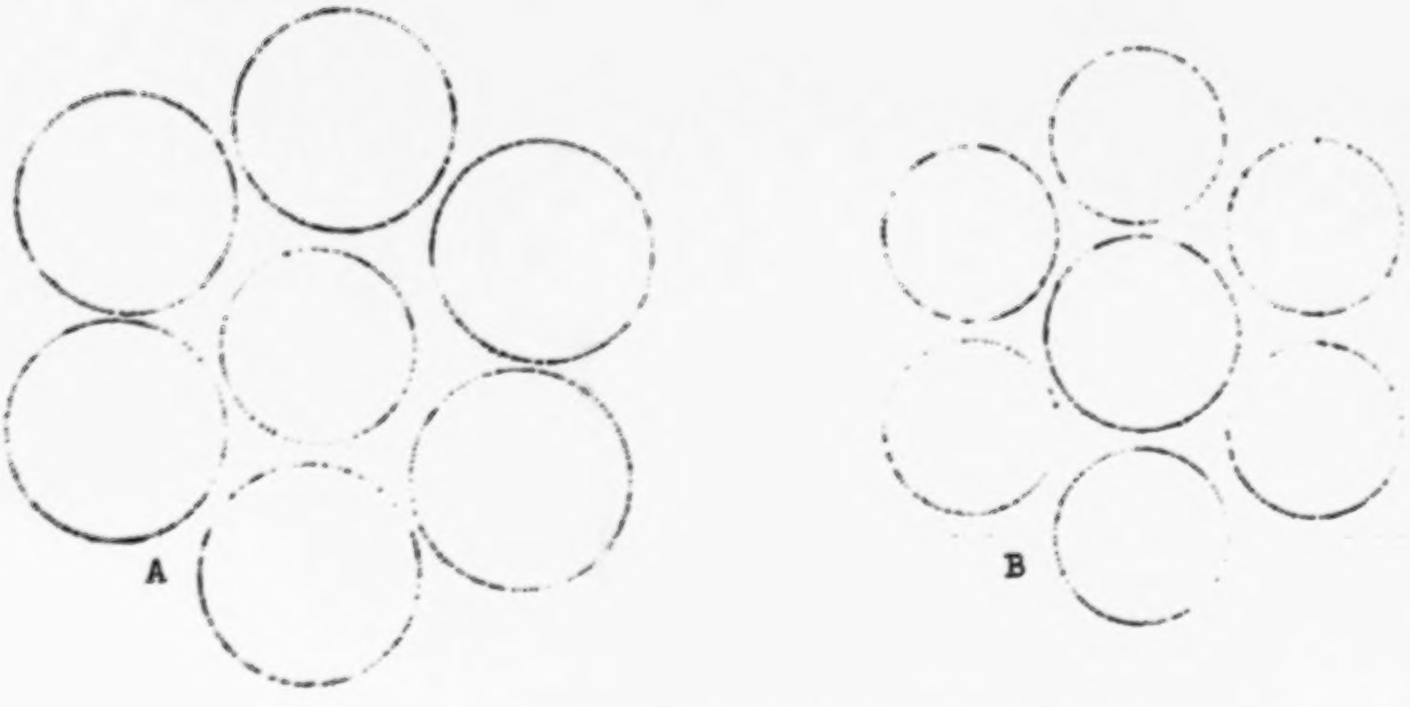


FIG. I.12 - Look at the center circle. Is the center circle in A the same size as the center circle in B?

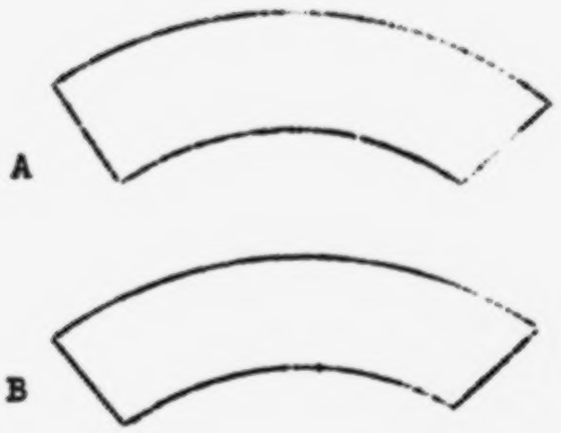


FIG. I.13 - Which is larger?

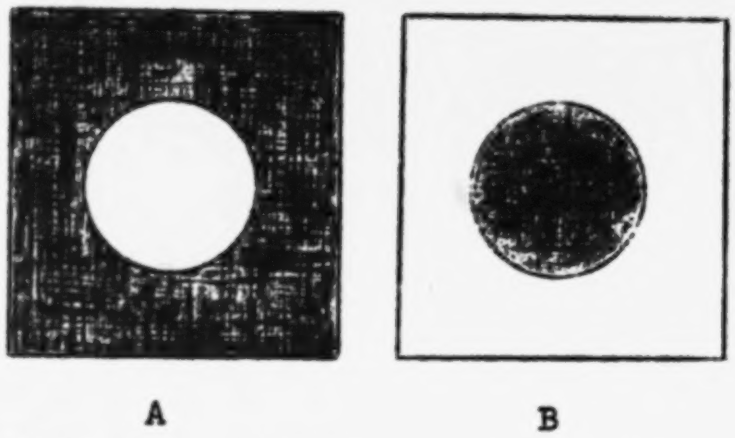


FIG. I.14 - Which circle is larger?

Now that you have recorded your answers, check to see if you are right. Which one in each case is actually larger? Record the answers in your lab book.

Exercises for Home, Desk and Lab (HDL)

(1) Notice that the measurements listed on the board differ somewhat. What are the possible reasons for these differences?

(2) Let's say, for example, that two measurements are given for the line, one 3.5 cm; the other 3.55 cm (assume that the ruler is accurate). Since the ruler or meter stick is marked in tenths of a cm is the second number acceptable?

(3) Would a measurement of 3.558 be better in this case?

(4) If you wanted a measurement to the third or fourth place, what might you do?

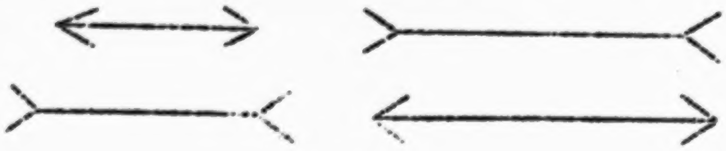
(5) If you wish to report the results of the measurements on the board, which number would you choose?

I.4a - METROLOGY

Metrology refers to the science of measurement. Scientists are necessarily concerned with the need to make more and more accurate measurements and with the problems involved in doing so. For example, if the bearing hole of a guidance gyroscope is off a millionth of an inch (and if no "in-flight" corrections could be made), it is estimated that this could cause a satellite to miss the moon by 1,000 miles.

Man measures extremely small distances. He can, however, never be absolutely accurate. Measurement is not exact.

Use these lines as an example:



If you were asked to count them without concern for length, your answer would be four. Counting is exact and discrete. Now if you are asked to measure them, you might use one line and compare the others to it. You might answer that one line is twice as long; the other is two-and-a-half times as long and the other is three-and-a-half times as long as the shortest one. Measurement always involves comparisons and that is what was done here where the shortest line became the standard. But if you are trying to tell someone else how long the lines are and they cannot see the shortest one, this procedure would not be very useful.

Maybe you could pick a standard such as a paper clip which is fairly uniform in length and is an object that is familiar to all. In using this, you might get such answers as 1½, 1, 3/4 and ½ paper clips. Except for 1, the answers given are not whole numbers nor are they multiples of one paper clip. You must estimate the fraction. To make this easier, you might mark the paper clip off in equal parts. But how many divisions do you make? The distance between the ends of the paper clip are continuous so the divisions can be made again and again. You might divide it into tenths, but then each of these divisions could be divided in two so that the markings would now be .05 of the paper clip. Obviously there is a practical limit to the number of divisions that can be made. This is true regardless of the instrument. Measurement is therefore inexact and uncertain.

The number of divisions on a measuring instrument such as a ruler will be sufficient depending on how the ruler is used. Remember the limitations of the instrument. It is unreasonable to try to measure a tenth of a second with a wrist watch; it is also unreasonable to try to measure a thousandth of a cm with a ruler.

If the work you are doing requires a more exact measurement, you must have a better instrument. But even with the best instrument, an absolutely exact measurement cannot be found. The divisions could be divided further.

Another problem exists. The device used to measure often affects the object being measured. For example, if light is being used, the object being measured will expand. An error is introduced.

Scientists using even the most accurate measuring tool still take many measurements and average them and they still consider and report in terms of the probable error.

I.5 - Experiment: USING ILLUSIONS

In FIG.I.10 do you get the illusion of depth? Artists often make use of this illusion (which they call perspective). Have you seen examples in which "pop" artists use lines and colors to create illusions?

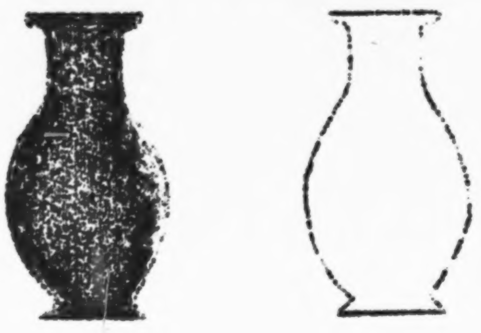


FIG. I.15

In the picture above the lighter object looks larger. The next time you go into a grocery store, notice how many packaged foods are in light colored containers.

Dress designers also make use of illusions. A black dress makes you appear thinner. They also might consider how lines affect your appearance. Which of the identical girls below looks thinner?

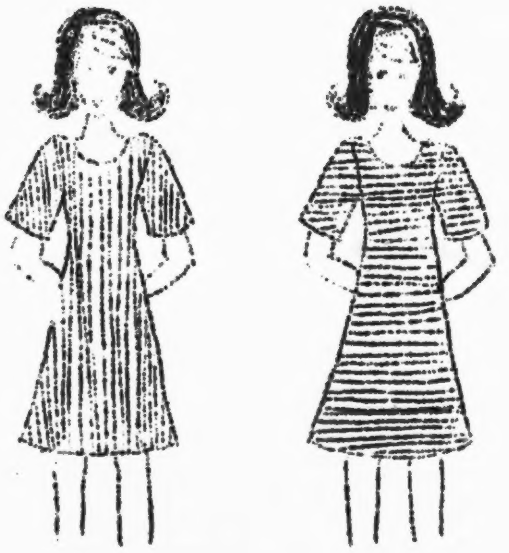


FIG. I.16

Can you think of other examples of using optical illusions?

I.6 - Demonstration: LIGHT AND COLOR

Most of you have seen a prism before and know what it does to white light. Now you should look again more carefully and with some thought. What do you conclude about the nature of "white" light? Can you recall from your own experience the names of some kinds of light which are invisible to the eye? Do you have any means of perceiving these? Do any other living organisms have means of perceiving these?

If it is true that white light is the result of mixing colored light, then you should be able to reverse the effect of the prism by mixing various colors of light to produce white light. Although this could be done using the light output of the prism, it would be complicated and it is easier to do it by means of color filters which remove from white light all but one color. Try it with the colored lights provided by shining them into the beaker filled with the milky liquid. The color obtained is to be observed through the window cut in the black cover placed on top of the beaker. What happens when you mix red and blue or red, blue and green? Do we need all of the colors shown by the prism in order to get white? Do you think that the color filters used give a "pure" color? How could you test this? What is the purpose of the milky liquid?

I.7 - Demonstration: SEEING THROUGH HEARING

You have heard of bats flying at dusk and you know that airplanes fly at night. Submarines navigate underwater. What are your "seeing" powers when blindfolded? Your teacher will show you how to "see" with your ears.

I.8 - LIMITATIONS OF OUR SENSES

In Experiment I.4 - SIZE ILLUSIONS, probably most of you chose the same figure as being the larger. But when you observe things, do you all perceive (see, feel, smell, hear, taste) the same things in the same way?

You know that some people like the taste of olives, some do not. Is this because they taste differently to some? You know that your environment and learning have an effect on how you perceive and on your choice of what you like or don't like. But do you actually know whether or not all people taste the same thing in the same way?

When you see something that is blue, does it look exactly the same blue to someone else? Since there is no way to measure or quantify your perception of blue, there is no way of comparing and communicating with others as to what you actually are perceiving. Therefore, there is no way to tell whether or not the blue looks exactly the same to someone else.

Your senses are limited in several important ways. You will conduct a series of experiments to determine the nature of some of these limitations. Since in these experiments you will be making some measurements, you will be able to make some comparisons as to similarities and differences among sense perceptions.

There are seven experiments to be done:

Touch
Taste
Depth Perception
Peripheral Vision
Response Time of the Eye
Visual Reaction Time
Auditory Reaction Time

The teacher will assign lab groups and give directions. He will also assign the order in which each group is to do the experiments.

Read carefully these instructions:

(1) Read the directions and background material for the experiment you will be doing before you come to class. (time is limited).

(2) In class work quickly but carefully. You will be expected to do one experiment, collecting and recording all of the necessary data in about one lab period.

(3) You will be expected to do some of the data compiling, mathematics, graphing and questions at home. (The teacher will need to take some time in class for those who need help and for general instructions and discussion.)

(4) If the equipment you need to use is busy, while you are waiting, use the time to compile data and answer questions. If you have time, work on some of the suggestions for further study and experimentation.

I.9 - Experiment: TOUCH

Spread the points of a compass (divider) to 4 cm. Touch the points of the compass to the forearm of a blindfolded lab partner. Ask if there are two points or one point touching his arm. Record the distances and the student responses. Move the points of the compass closer together. Record the distance that your lab partner reports as a single touch when two points are actually touching his arm. Remember to use an occasional one-point touch as a control or otherwise he will know that he is being touched with two points every time. Repeat this process on the tip of a finger. What do you find about the sense of touch for a finger compared to the forearm?

Does your sense of touch differ from that of your lab partners? Does the alignment (parallel or perpendicular) of touching upon the forearm change the measurement?

I.10 - Experiment: TASTE

(A) You will be given a sugar solution. Determine at what dilution you can no longer taste the sugar by making a series of dilutions of the original solution. To do this, add an equal amount of water to the original sugar solution. Be sure to mix the solutions well then taste about one spoonful. Rinse your mouth after each testing. Pour about one-half of the diluted solution into a clean test tube and add an equal amount of water. Again mix well and taste. Continue this process of dilution, mixing and tasting, being sure to record your operations until you can no longer taste the sugar. The point at which you last taste sweetness is your taste threshold for sugar.

Does your taste threshold differ from that of your lab partner's?

(B) You will be given a saccharin (low-calorie sugar substitute) solution. Determine how much sweeter the saccharin is than the sugar.

(1) Explain how you could prepare a solution that is one-third the concentration of your original solution.

(2) If the best balance available will weigh no less than 1 gram explain how you could prepare a solution containing only 0.001 gram per milliliter.

I.11 - Experiment: DEPTH PERCEPTION

The object of this experiment is to try to line up the two pens by moving one of them. You will need three people in your lab group. One student is the subject (S), one is the experimenter (E) and one is the recorder (R). After twelve trials change roles and repeat the procedure for twelve trials. Then again change positions. Each of you will then have performed each of the roles of S,E and R.

As S you will sit at the table and look at the pens either (1) through a hole in the cardboard screen that allows you to use only one eye (either the left or right) with no head motion (monocular condition), (2) through a wide hole in the cardboard screen that allows you to use both eyes and no head motion (binocular condition), or (3) with the cardboard removed allowing you to use both eyes and head movement (motion parallax condition). Keep your head low enough so that the meter stick is not visible to you.

R will give you the proper condition to use. Take the string and adjust the moveable pen to and fro until you think you have it lined up with the stationary pen. You have then judged them to be the same distance from you.

As E, between each trial you will change the standard pen (the one that cannot be moved by S) to a new position and adjust the moveable pen to the front or back of the meter stick. Why should this be done?

When S informs you that he has the pens lined up, give the error score to the recorder. This error score is the number of centimeters (to the nearest 0.1 cm) that the moveable pen is from the standard pen. If the moveable pen is too far from S, give the direction of error as minus (-); if it is too near, give it as positive (+).

As R, you record for S, Make a chart as follows:

Trial	Condition	Error Score	Direction of Error (too near +) (too far -)
1	Monocular		
2	Monocular		
3	Binocular		
4	Binocular		
5	Motion Parallax		
6	Motion Parallax		
7	Motion Parallax		
8	Motion Parallax		
9	Binocular		
10	Binocular		
11	Monocular		
12	Monocular		

Why are the conditions varied? You give the condition to be used for each trial to S. As R, record the error score and direction of error as given to you by E.

Exercises for Home, Desk and Lab (HDL)

(1) Write a conclusion concerning the effects of the three different conditions on depth perception according to the data taken on you.

(2) What were your average scores for each condition? Why are you asked to find the average rather than to choose one score? What is your average when you disregard the + and - signs? What is your average when you consider the + and - signs? Which is more meaningful? Compare your averages with others in the class.

(3) Is there any pattern in your data of + or - errors for any condition? Compare your findings with others in the class.

Questions for Further Study or Experimentation

(1) With the monocular condition you used only one eye. Will you get the same approximate results using the other eye?

(2) Will you have better scores on the monocular condition if you are allowed to move your head?

(3) Some of you wear prescription glasses. Do you get better scores with or without your glasses?

(4) A quarterback on a football team would need to have good depth perception. Would a person who had lost an eye ever be able to become a good quarterback?

I.12 - RELIABILITY AND VALIDITY

You may wonder at this point if a good score in depth perception in this experiment will mean that you will be a good driver. Of course the answer is no. There are too many factors involved in driving a car to expect that one thing would determine whether or not you are a good driver. You might argue, however, that depth perception would be an ability you could have that would improve your driving. You will indeed need to judge depth while driving. But don't be misled. This experiment is reliable but it is not valid for all situations involving depth perception. By reliable we mean that if the experiment is repeated, you will get the same scores as before. This experiment is reliable. By valid we mean that there is a useful relationship between results of this experiment and some other related performance. This experiment is not valid for measuring the ability for depth perception in all situations.

A very similar experiment was used to test airplane pilots. It was found that some of those who did very poorly in the experiment had very good depth perception as pilots.

So you may have a much better score than your lab partner in this experiment, but while driving, he may be able to judge the distance to two approaching cars more accurately than you.

I.13 - Experiment: PERIPHERAL VISION

How far can you see to the side if you keep your eyes focused straight ahead? Can some people see farther to the side (peripheral vision) than others?

Does color have any effect on your peripheral vision?

You will need three people in your lab group. One student is the subject (S), one is the experimenter (E) and one is the recorder (R). After twelve trials change roles and repeat the procedure for twelve trials. Then again change positions. Each of you will then have performed each of the roles of S, E and R.

As S, you sit in a chair in front of the equipment. Make a loose fist with your hand and place it on the table in front of you. By resting your chin on your fist, you keep yourself as much as possible from moving your head. If this is too uncomfortable, use books under your fist. Also, the white X mark on the cardboard and the colored dots on the moveable cards should be at eye level, so make adjustments by using books.

Choose the eye you wish to use and cover the other with your hand (or blindfold for that eye if available). Stare straight ahead at the white X mark.

There will be a great tendency to move your eyes. If you give in to this temptation, you should inform E so that trial can be disregarded. Your results will not be reliable unless this is done.

As E, you place one of the moveable cards over the cardboard on S's preferred side. Hold it so that it is flat against the inside of the cardboard. Place it at the farthest lateral position (90) and move toward the center (0) until S identifies the color of the dot, not the motion or the card. Give directions that S is not to guess but to report only when he is certain he can identify the color. When S identifies the color, report the color and proper response position (actually the number of cm from 0) to the recorder. Be sure to read from the mark on the card each time and not the edges of the card. Why?

Each of the three colors (red, blue-green and yellow) should be presented about four times. The order in which you present the different colors should be randomly selected--for example, red, red, yellow, blue-green, yellow, etc. Why should the colors be presented randomly?

Also be sure that you give no clues to S as to what the color might be. For example, do not take a longer period of time, make a different sound or move in a different way when changing colors. Move each color at about the same speed.

As R, you are to record the data for S. For example:

Trial	Color	Response Position
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

The color and response position is given to you by E.

Exercises for Home, Desk and Lab (HDL)

(1) What is your average response position for each of the three colors?

(2) You had four response positon numbers for each color. Why were you asked to give the average (also called the mean) instead of the highest or lowest number?

(3) Compare your results with other members of the class. What similarities do you find? What differences?

(4) What is your explanation for seeing one color before you can see the other colors?

Questions for Further Study and Experimentation

(1) As E, you were instructed to select the colors randomly and to give no clues as to what the color was to be. Would it make any difference in your data if you knew what color was to be presented? Check your hypothesis by experimentation.

(2) If you use the other eye do you get the same results?

(3) If you are allowed to move the eye, will you get substantially better results?

(4) If you wear glasses, would this have an effect on your results?

(5) White is a mixture of colors. What results would you get in using white?

(6) Do you know of any animals that have independent eyes? What does this mean?

There is evidence that this experiment is reliable, but there is no evidence that it is valid for the driving situation (refer to I.12). You may have received a very low average response position as compared to others, but in driving a car you might be just as quick or quicker than others to notice another car coming up beside you or approaching from a side street.

I.14 — Experiment: RESPONSE TIME OF THE EYE

Like many "event-recording" instruments, the eye has a response time. That is, it takes a certain period of time for the eye to process and transmit an image and to prepare itself to receive a new one.

If a second, different image succeeds the first in a time less than what the eye requires, then the two images become scrambled and we "see" a mixture of both.

Using a phonograph turntable and a series of color wheels, you will now try to determine what the response time of the eye is. Since the speed of rotation of the turntable is fixed, you will vary the speed of image succession by changing the width of the colored sectors on the wheel.

Because the eye tends to follow a moving object, it will be necessary for you to fix your vision on some stationary point just above and beyond the edge of the rotating color wheel. You may want to look through a tube made of a sheet of paper to help in this process.

The sequentially numbered blue-yellow color wheels are constructed such that each wheel has twice as many sectors half as wide as those of the preceding wheel. Thus the number of images presented to the eye per second will be doubled when the second wheel is spun at the same speed as the first wheel.

In addition, materials are provided so that you can, if you have time, build wheels with other sector widths and other colors.

Now spin the wheels in their numbered sequence and observe each one as described. With which wheel do you first see a color change? What color do you see? Do you see this color change sooner if you fix your vision on a point farther above the wheel?

With the meter stick provided, measure and record (in centimeters):

(1) the diameter of the wheel and

(2) the width of each colored sector at the outside edge of the wheel.

Using a stopwatch or the sweep hand of a wall clock, determine the speed of your turntable in revolutions per minute (rpm).

Using the three numbers you have obtained and knowing the equation which relates the circumference of a circle to its diameter, you should now try to calculate how long it takes one sector to pass a fixed point at the edge of the wheel. Is the time interval you calculate what you would have guessed for the response time? Do you know how many frames (pictures) per second are shown in a motion picture? How does this number relate to the response time of the eye? Looking back at the sequence of wheels which you tested, can you estimate how accurate your calculated response time is? To put it another way, do you think the response time could actually be almost twice as long? Half as long? You may want to build your own wheel to obtain a more accurate answer.

A black-white wheel attached to a hand drill is provided. As you spin it faster and faster, do you "see" color anywhere on the wheel? What happens if you spin it in the opposite direction? Now look carefully at the pattern of black and white on the wheel. Can you see any relationship between where you saw color and the pattern of the wheel?

I.15 - Experiment: VISUAL AND AUDITORY REACTION TIME

You have done or will do several experiments on visual perception. This experiment will also involve auditory perception. You are to determine your reaction time to a visual stimulus and compare it to your reaction time to an auditory stimulus. Also compare your visual reaction time found in this experiment to the response time you find for the eyes in the experiment with the color wheel.

You will need three people in your lab group. One student is the subject (S); one is the experimenter (E); and one is the recorder (R). After fifteen trials for the visual reaction time, change roles and repeat the procedure for fifteen trials. Then again change positions. Each of you will have then performed each of the roles of S, E and R. Follow the same procedure for the auditory reaction time experiment. It is suggested that when you change roles, R becomes S, S becomes E and E becomes R. As E and S, you may become tired and fatigue could affect your reaction time.

Use the Pieron sticks which are meter sticks with calibrated strips of paper attached to them. These strips of paper are calibrated in hundredths of seconds. Can you explain how this calibration was done?

Choose a smooth-surfaced wall where you will have plenty of room to work. The edge of a cabinet, a door casing or an outside corner may be easier to use.

E places the stick against the wall at a height where the .00 mark is convenient for S. E. holds the stick to the wall by the pressure of his thumb. He aligns the stick vertically at each trial.

S places his thumb about 1 cm away from the stick with the .00 mark in line with the top of his thumb. He supports his hand against the wall.

E should say "Ready" about 1 to 4 seconds before suddenly jerking back his thumb to allow the stick to fall freely.

S watches E's thumb or the stick. When he sees the thumb move or the stick start to fall, he applies pressure with his own thumb to stop the fall of the stick.

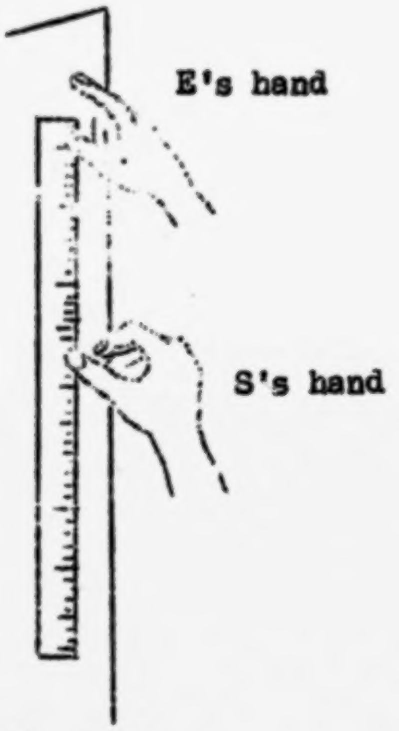


FIG. I.17

E reads the reaction time that is nearest in line with the top of S's thumb. Why should the time be read from the top of the thumb?

E should vary randomly the length of time between the "ready" signal and the release of the stick. Why?

R records for S. Record the visual reaction time for each of fifteen trials.

After each has recorded fifteen visual reaction times, find your auditory reaction times.

K.16 - Experiment: AUDITORY REACTION TIME

The procedure is exactly the same except the subject (S) is now blindfolded. E holds the stick against the wall with a toy mechanical cricket. E must place S's thumb in the proper place each time, or place the stick so S's thumb is in the proper place with the top of the thumb in line with the .00 mark. Again the thumb should be about 1 cm from the stick.

E presses the stick against the wall with the cricket. He should press hard enough to hold the stick with the cricket. That way the cricket clicks only once. E gives the "ready" signal and in from 1 to 4 seconds jerks the cricket away. This causes the second click to sound from the cricket and allows the stick to fall at the same time. E. should practice this a few times to develop the technique before testing S (hold the cricket with the thumb on top and one finger under the side).

As soon as S hears the click, he moves his thumb to catch the stick.

E reads the auditory reaction time and R records it for S. Record the times for fifteen trials.

When you have completed the fifteen trials for all three students for both the visual and auditory reaction times, take your own data and compile it as shown in the following example:

VISUAL		AUDITORY	
Seconds	Frequency	Seconds	Frequency
.04	0	.04	0
.05	0	.05	0
.06	0	.06	0
.07	0	.07	0
.08	1	.08	1
.09	0	.09	0
.10	0	.10	11
.11	11	.11	1
.12	1	.12	11
.13	1	.13	1111
.14	111	.14	11
.15	1111	.15	11
.16	11	.16	0
.17	0	.17	1
.18	1	.18	
.	.	.	.
.	.	.	.
.	.	.	.
.	.	.	.

By frequency we mean the number of trials in which you got a certain reaction time.

In the above example, for the visual, if you caught the stick in .15 seconds on four different trials, the frequency for .15 seconds is 4. If you caught the stick in .16 seconds two times, then the frequency for that time is 2.

Also add your data to the master sheet that the teacher has prepared for the class. Add the proper number of

marks (frequency) to each time column.
Put these marks about equal distances
apart.

Graph your results. Label the X axis time in seconds, the Y axis, frequency. In graphing your data you will get what is called a frequency distribution curve. You may make two separate graphs, one for the visual reaction times. In order to compare them, however, label each graph the same way. You may put both graphs on the same graph paper. Use a different color for each for easier reading.

Exercises for Home, Desk and Lab (HDL)

(1) Compare your graph for the auditory reaction time to the one for the visual reaction time. Are the shapes of the curves similar? Do they peak near the center? Are they somewhat symmetrical? How does the range (the amount of spread of values) of one differ from the other? In which case would you think you would get a shorter reaction time?

(2) Compare your graphs with the graphs from other members of the class and with the graphs from the entire class. What similarities and differences do you see?

(3) What was your shortest reaction time for each stimulus? What was your longest time for each stimulus? What was your average reaction time for each stimulus? Which ones should you report as your reaction times? Why?

(4) Are your mean or average scores the same for both the auditory reaction times and the visual reaction times? Check your results with others in the class. Are the differences between the two scores about the same in magnitude and direction (auditory or visual)?

(5) Do you believe that one can, on the average, react faster when receiving a signal from one sense than he can if he receives a signal from another sense? What evidence do you have to support your belief? What degree of confidence do you place on your evidence?

(6) How do you account for differences in your visual reaction time in this experiment as compared to the response time of the eyes that you found in the experiment with the color wheel?

(7) What might cause the reaction time scores to fluctuate? To what extent are these fluctuations predictable? Can you think of any ways to reduce the fluctuation?

(8) What are some factors that may affect your reaction time?

The experiments on reaction times are both reliable and valid. If your reaction time was faster than average in the experiment, it is very probable,--if there is nothing to affect your reaction time,--that you will react faster than average in other situations. While driving, if an emergency arises, you probably will be able to hit the brake faster than the average driver. Again, this will not make you a good driver. There are too many other factors to consider, but the point to be made here is that these experiments on reaction times are valid. There is a useful relationship between the results of the experiment and some related performance.

From materials you have already studied, you have seen that your senses are subject to a sensitivity threshold, a time threshold and to illusions. You have also seen that various instruments or tools may help to overcome sensory limitations. Yet, even those instruments that are most used to extend the senses have limitations and lead to special illusions. We will illustrate these limitations and illusions using a microscope as a convenient and widely used sensory extender.

I.17 - BSCS Green Experiment 1.4: USE OF THE MICROSCOPE

I.18 - Experiment: PARAMECIA AND THEIR SPEED

Using a medicine dropper, remove a small amount of liquid containing paramecia. Place one drop at the center of a clean glass slide and add a cover slip. Focus with low power and adjust the substage diaphragm to obtain good contrast. Move the slide around on the stage so that all areas under the cover slip are examined. Notice the movement of the organisms. When seen under high power, do the organisms appear to move more rapidly or more slowly than when seen under low power? Guess how rapidly the organisms are moving. Knowing the diameter of the circular field of view and approximately how long it takes a paramecium to cross that field, what is the speed of the paramecium? Contrast this speed with your speed of normal walking by expressing both values in the same units.

I.19 - Demonstration: SIZE AND WEIGHT

In this demonstration volunteers will be asked to judge relative weights and to make estimates of actual weights.

Exercises for Home, Desk and Lab (HDL)

(1) Do you think being able to see the cans will help or hinder the students in making their judgments of weight? How would you test your hypothesis?

(2) Do you think the students would make better judgments if they had a known weight with which to compare the unknown ones?

(3) Examine the data on the board. Are there any conclusions you can draw from these data? In the first group did the volunteers consistently judge one of the cans heavier than the other? If so, how might you account for this? In the second and third groups, did the volunteers consistently judge one can heavier than the other? Try to explain any similarities and differences in the judgments of the three groups as to which can was heavier. Is there any consistency

in the judgments as to "times heavier" or in the actual estimates of weight? Did one group definitely make better judgments than the other groups? If so, try to explain why.

(4) What degree of confidence do you have in the conclusions you made? What factors can you think of that might have caused you to draw a faulty conclusion?

(5) Are the weights of the cans constant? That is, would they weigh the same no matter where you are?

(6) How accurate were the estimates of actual weight? Is there a need here to use a tool to extend our senses? What would be used?

Questions for Further Study and Experimentation

(1) Students were asked to lift the cans by hooking one finger under the handles. Was this really important? Lift the two cans by placing them on the palms of the hand. Lift them with one finger under the handles. How do you account for the difference? If you had no handles for the cans and had to lift them with the palms of the hand, what should you do?

(2) Would you be able to make better judgments of relative weights if you were allowed to swing the cans back and forth?

Chapter II: Measurement, Distribution, Organization and Communication

IPS ('67 ed) - Chapter II: QUANTITY OF MATTER: MASS

II.1 - VOLUME (IPS II.1)

II.2 - MEASURING VOLUME BY DISPLACEMENT OF WATER (IPS II.2)

Only read this section. Your teacher will demonstrate.

II.3 - Demonstration: VOLUME BY WATER DISPLACEMENT

II.4 - SHORTCOMINGS OF VOLUME AS A MEASURE OF MATTER (IPS II.3)

II.5 - MASS (IPS II.4)

II.6 - Experiment: THE EQUAL-ARM BALANCE (IPS II.5)

II.7 - Experiment: THE PRECISION OF THE BALANCE (IPS II.6)

II.8 - Experiment: BEADS AND GRAMS (IPS II.7)

Exercises for Home, Desk and Lab (HDL)

(1) In Experiment I.19 you made estimates of mass. How is your judgment of volume? How much greater is the volume of the larger can? Estimate the actual volume.

(2) What are the differences in the density of the two cans?

II.9 - MEASUREMENT AND UNCERTAINTY

We have stressed the use of instruments as aids in extending our senses, but is there a limit to our sensory aids just as there are limits to our senses? As we might expect, every measurement does indeed have some uncertainty.

To begin a study of the nature of measurement, a problem should be proposed that requires some kind of measurement for its solution.

Which of the shaded areas to the right has more area? Even more specifically, what is the ratio of area A to area B?

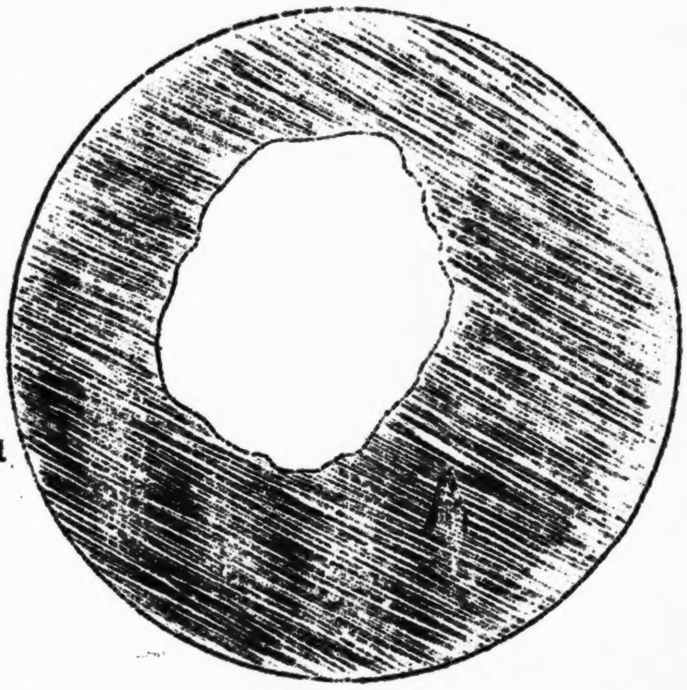


FIG. II.1 - A

A quantitative answer is needed. You should be able to say something like, "I think the ratio of B to A is 1.5/1.0." What ratio did you get? What method did you use?

One method that can be used is called square counting. Lay a piece of graph paper on top of the shaded figures and trace their outline. (We want the shaded area only.) Now count the squares within each. In this way we can find each of the areas. To get the ratio of area B to area A, divide the area of B by the area of A. Try it.

On graph paper with squares 1/10 of an inch on a side, there are 592 squares in A and 666 squares in B. This means the ratio of B/A is 1.13/1.00.

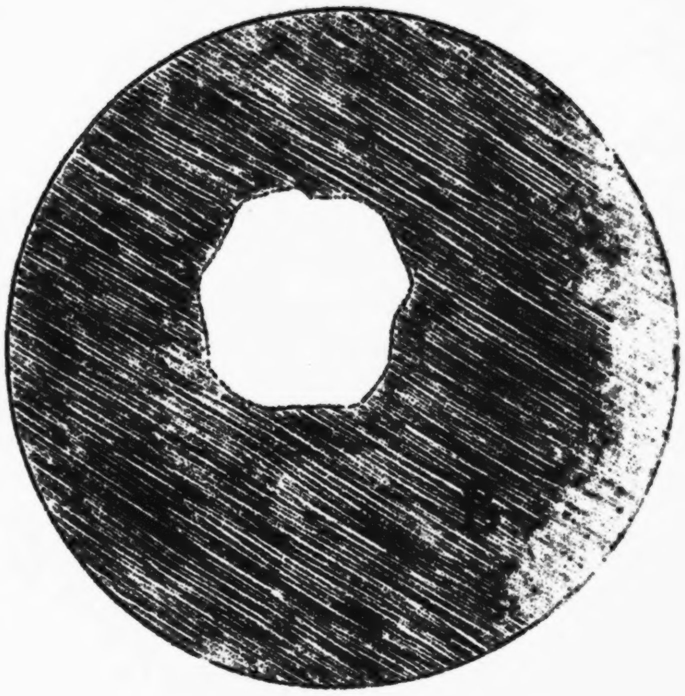


FIG. II.1 - B

Now let's examine what we have done. We chose a certain sized square and counted how many fit into the odd-shaped areas. This leads to a very important principle: all measurement is counting. In measuring anything, we choose a basic unit and ask how many of the basic units will fit into the object being measured.

II.10 - SYSTEMS AND UNITS OF COUNTING

Suppose we had used a different sheet of graph paper which had larger squares. What difference would this have made? We could have found a lower count for both A and B, but they would have been lower by the same factor. For example, if the squares had been twice as large, the count for both A and B would have been one-half the original count. The ratio of the areas would be the same no matter what size squares were used. We would have employed a different system of measurement with a different basic unit, but our conclusion would remain unchanged. Unfortunately, several systems of measurement such as the metric system and the English system are in use today. This makes the job of understanding the universe a bit more complicated than it might otherwise be.

II.11 - DISTANCE, MASS AND TIME

Although man has made many sophisticated measuring instruments, he is still basically able to make only three measurements. These measurements are

(1) measurements of distance [D],

(2) measurements of mass [M], and

(3) measurements of time [T].

All other measurements are combinations of these three

For example, the measurement of area that we just described is a combination of measurements. Area is distance multiplied by distance, therefore expressed as D^2. In fact, area is always some factor multiplied by distance times distance. The area of a triangle is equal to the factor "½" multiplied by the distance (the base) multiplied by the distance (the height). What is the factor in the equation for finding the area of a circle?

If we analyze the arrangement of these three basic measurements, we say we are doing a dimensional analysis. For instance, you have found that the dimensions of area are D^2. What are the dimensions of volume? As you know, the room you are in has three measurements. They are height, length and width. But all of these are really one dimension--i.e., distance.

The analysis of dimensions can be a powerful tool in problem solving. If you are trying to determine volume and your answer does not have the dimensions of volume, D^3, your answer is obviously wrong.

In the metric system, the basic units are seconds for time, meters for distance and kilograms for mass. This system is often referred to as the MKS system.

II.12 - Experiment: THE SCALENE TRIANGLE

Carefully trace around the aluminum triangle given your group by the teacher. It is called a scalene triangle because it has three different bases and heights. Label the three points of your drawing A, B and C and consider the heights to be h_a, h_b and h_c as in the adjoining figure. Calculate the area of the tracing using base AB and h_c. Make your distance measurements and give your answers

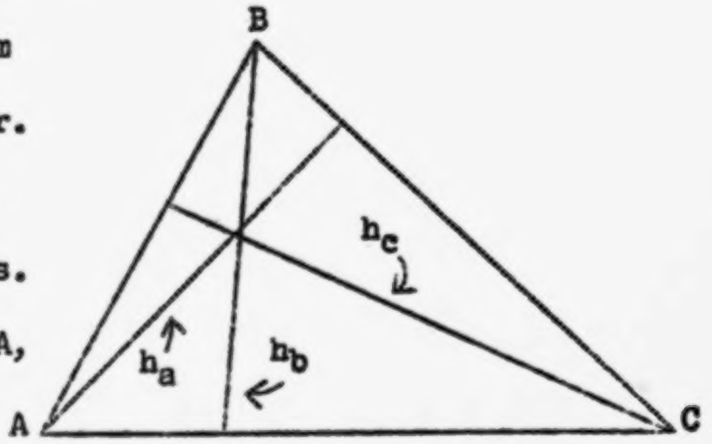


FIG. II.2

using the basic units of the MKS system. Calculate the area of the triangle using the base AC and the height h_b. Finally calculate the area of the triangle using base BC and h_a. Did you get the same answer all three times? Why? Perhaps the trouble lies in the way you made your measurements. Keep your data and tracing for the scalene triangle for later; you will want to refer to it.

II.13 - UNCERTAINTY ASSOCIATED WITH MEASUREMENT

You have made many measurements while doing the exercises and experiments associated with this course. After working with the scalene triangle, you very likely realized as you did in section I.4a that there was some uncertainty associated with every measurement you made. You have discovered one of the major problems all scientists have: no measurement is exact. There is some uncertainty associated with every measurement. It follows that science is, to some extent, uncertain. It is the extent of this uncertainty that is of interest to us now.

II.14 - UNCERTAINTY ASSOCIATED WITH INSTRUMENTS

We can begin our search to find out why our answers for the area of the scalene triangle varied by analyzing a linear measurement. Imagine that a professional scientist is interested in determining the area of a scalene triangle similar to the one we worked with. The picture below is a representation of what the scientist sees as he measures the base of his triangle:

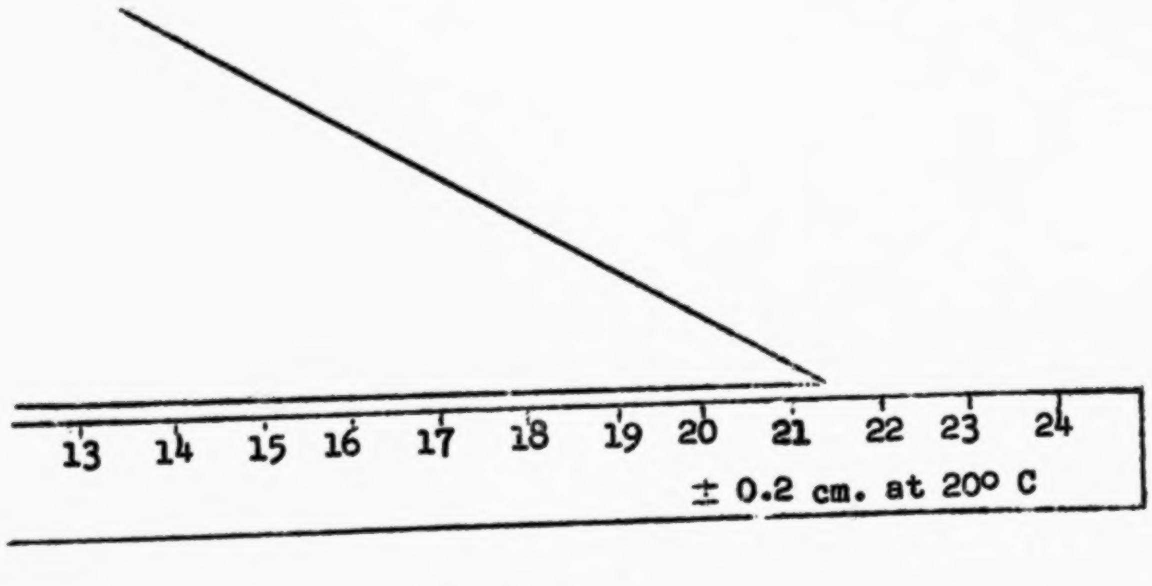


FIG. II.3

Notice that the rule is marked plus or minus 0.2 cm when the temperature is 20° C. This means the rule may be longer or shorter than we think it is. It may be 0.2 cm longer or it may be 0.2 cm shorter. The manufacturer of the rule guarantees the rule is never off more than 0.2 cm in either direction if the temperature is 20° C. Here then is a clear indication of one of the major sources of uncertainty--instrumental error. Every instrument has some error associated with it. Unless the instrument is quite expensive, it usually does not have the plus or minus (±) engraved on it. Some of the typical uncertainties associated with instruments found in most science laboratories are listed in the following table:

Instrument	Typical Uncertainty
Triple-beam centigram balance	± 0.01 g
50 ml graduated cylinder	± 0.2 ml
Platform balance	± 0.5 g
50 ml gas measuring tube	± 0.02 ml
50 ml buret	± 0.02 ml

In some cases if you cannot find the uncertainty of the instrument you wish to use, you will have to make an intelligent guess. Your teacher may be able to help you make this guess.

II.15 - HUMAN UNCERTAINTY

If the scientist knows how to read his rule, he will begin by mentally dividing the smallest marked division into tenths. This means he will read this particular rule (FIG. II.3) to the nearest 0.1 cm although it is marked to the nearest centimeter. Keeping alert to anything that might deceive his senses, the scientist makes his reading. He reads the length of the object as 21.5 cm. He would not stop there, however, because he is not finished with the measurement. He would say to himself, "I may be off as much as 0.1 cm in my reading because I mentally divided the smallest division on my rule into tenths. Therefore, my human uncertainty may be as much as ±0.1 cm." This type of uncertainty associated with measurement is called human error.

II.16 - UNCERTAINTY DUE TO CHANGES WITHIN THE SYSTEM

Can you think of any way the triangle might be changed because of the measurement? Perhaps the scietist holds the aluminum triangle in his hand and, as the result of a heat exchange, the triangle changes size. Perhaps the rule is much warmer than the object; as a result of contact, the object changes. In this particular measurement the error due to a change within the system would be very small--so small, in fact, that the scientist would say it was negligible. He would assign ±0.0 cm for this error.

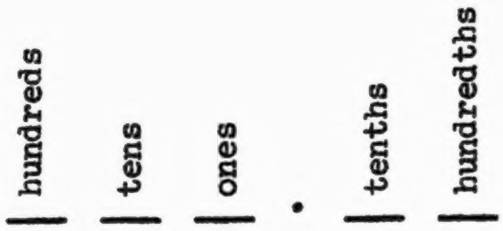
You might think this category of error is not a major category and should itself be neglected. If we make measurements of ordinary objects, this category usually can be neglected. There are systems, however, where the process of measurement disturbs the system sufficiently to cause sizeable errors in measurement.

II.17 - RANGE OF UNCERTAINTY

The three categories of error, then, are human error, instrumental error and error due to change within the system. In the example used, the scientist assigned a ±0.1 cm uncertainty as his human error. He assigned a ±0.2 cm for the instrumental error and 0.0 cm for the error due to change within the system. The scientist's reading was 21.5 cm. What final uncertainty should he assign to his reading? Before we can answer this question, we must think about the maximum amount the reading may be off. It is obvious that the scientist must add the human error, the instrumental error and the error due to change within the system. Therefore, the scientist tabulates his reading as 21.5±0.3 cm. The range of uncertainty is 0.6 cm, because the scientist is saying the actual length of the object lies somewhere between 21.2 cm and 21.8 cm.

II.18 - PLACE OF THE UNCERTAINTY

As you probably recall, we have names for the positions digits occupy in numbers. For example,



The place of the uncertainty is the same place occupied by the range of the uncertainty. In our previous example, 21.5 ± 0.3, the range of the uncertainty is in the tenths place. Therefore, the place of the uncertainty is also in the tenths place.

As another example, 168.9 0.3 cm poses an interesting problem. The number 168.9 plus 0.3 is 169.2. Does this mean the place of the uncertainty is the ones place? Not at all. The place of the uncertainty is still in the tenths place.

II.19 - ROUNDING OFF TO THE CORRECT PLACE

When scientists communicate quantitatively, it is generally accepted that the uncertainty is rounded off to the largest place having a digit. In this case zero is not considered a digit. For example, in the measurement 102.73 ± 1.689, the uncertainty (1.689) is rounded off to the ones place and therefore becomes 2. It is also generally accepted that the part of the measurement that comes before the uncertainty is rounded off to the same place as the uncertainty. The measurement 102.73 ± 1.689 becomes 103 ± 2 when rounded off properly. Before you read any further, round off the following measurements to the proper place.

(1) 421 ± 210 miles
(2) 6591.2 ± 12 meters
(3) 1.269 ± 0.068 centimeters
(4) 500 ± 109 seconds
(5) 50,000 ± 100 kilograms

Check with your teacher to be certain of your answers before you continue.

II.20 - PROPAGATION OF ERRORS

What happens to this "plus or minus" when you add, subtract, multiply or divide? The propagation of errors is too large a topic for exhaustive coverage here. We will learn a simple method accepted by most scientists called "significant figures."

II.21 - SIGNIFICANT FIGURES

Significant figures are the digits that are certain plus one more. The measurement 21.5 ± 0.3 has three significant figures. We are certain of the tens place and the ones place, but we are not certain of the tenths place. The uncertainty lies in the tenths place. Expressing this number using significant figures, we write 21.5. Determine the number of significant figures in the following measurements and express them using the proper number of significant figures. You may have to round off some of the measurements first.

(1) 251 ± 1 kilograms

(2) 6,532 ± 0.04 grams

(3) 500 ± 10 seconds

(4) 500 ± 1 centimeter

(5) 4.0002 ± 0.00149 square meters

II.22 - ADDING SIGNIFICANT FIGURES

When you add or subtract measurements, the number of significant figures in your answer is determined by the largest place where there is uncertainty. In the following example, the digit that is uncertain is enclosed in a box.

$$\begin{array}{r}
112.2\boxed{3} \\
100.\boxed{0} \\
519.169\boxed{8} \\
2.000\boxed{1} \\
\hline
723.\boxed{399\boxed{8}}
\end{array}$$

Keeping in mind that significant figures are the digits that are certain plus one more, it is evident there are four significant figures in the answer. The answer rounded off and expressed in significant figures is 723.4. Try the following problems and check them with your teacher before you continue. Round off your answers and express them in significant figures.

(1)
$$\begin{array}{r} 569.321 \pm 0.01 \\ 2.0009 \pm 0.0001 \\ \hline 1030 \quad \pm 2 \end{array}$$

(2)
$$\begin{array}{r} 49.8003 \pm 0.03 \\ 1.000 \pm 0.001 \\ \hline \end{array}$$

II.23 - SUBTRACTING SIGNIFICANT FIGURES

As in addition, the number of significant figures in the answer is determined by the largest place that has any uncertainty. For example,

$$\begin{array}{r} 32.\boxed{5} \\ -\ 8.59\boxed{8} \\ \hline 23.\boxed{598} \end{array}$$

The proper answer, rounded off, is 23.6. Try the following problems and check with your teacher before you continue.

(1)
$$\begin{array}{r} 973.00\boxed{9} \\ -70.00\boxed{4} \\ \hline \end{array}$$

(2)
$$\begin{array}{r} 523.0013 \pm 0.0235 \\ -34.00298 \pm 0.00069 \\ \hline \end{array}$$

II.24 - MULTIPLYING AND DIVIDING SIGNIFICANT FIGURES

When you multiply or divide, your answer should have no more significant figures than the smallest number of significant figures originally available.

For example,

$$\begin{array}{rl} 156 & \text{(three sig. figs.)} \\ \underline{365} & \text{(three sig. figs.)} \\ 780 & \\ 936 & \\ \underline{468} & \\ \cancel{56940} & \\ 56{,}900 & \text{(therefore,} \\ & \text{three sig. figs.)} \end{array}$$

$$\begin{array}{rl} 89453 & \text{(five sig. figs.)} \\ \underline{111} & \text{(three sig. figs.)} \\ 89543 & \\ 89543 & \\ \underline{89543} & \\ \cancel{10030283} & \\ 10{,}000{,}000 & \text{(therefore,} \\ & \text{three sig. figs.)} \end{array}$$

$$\frac{1943.1}{2.1} \quad \frac{\text{(five sig. figs.)}}{\text{(two sig. figs.)}} = \cancel{925.3} \quad 930 \quad \begin{array}{l}\text{(therefore,} \\ \text{two sig. figs.)}\end{array}$$

Try the following problems and check with your teacher before continuing.

Multiply:

(1) $\begin{array}{r} 269.4 \pm 0.1 \\ \underline{16.2 \pm 0.1} \end{array}$ (2) $\begin{array}{r} 1000.0 \pm 0.1 \\ \underline{1.0 \pm 0.1} \end{array}$

Divide:

(1) $\dfrac{569.129 \pm .02}{69.001 \pm .005} =$ (2) $\dfrac{4834.2 \pm .1}{1.0 \pm .1} =$

II.25 - SCIENTIFIC NOTATION

Unless we always attach the uncertainty to the measurements we make, it is difficult to convey to another investigator just where the uncertainty lies. For example, if we see the number 460,000, we cannot tell whether the uncertainty lies in the ones, tens, hundreds or thousands place.

To eliminate the confusion, scientists use a simple method which leaves no doubt as to the proper number of significant figures. This simple method is called scientific notation. We all know the decimal point moves one place to the right every time you multiply by ten. We also know the decimal point moves one place to the left when you divide by ten. To express a measurement using scientific notation, the recorder simply writes the proper number of significant figures, puts the decimal between the first and second digit, then multiplies or divides by the proper number of "tens" to make the measurement as large or small as it actually is.

For instance, if the recorder wishes to tell the person who reads his report that the measurement is 460,000, good to three significant figures, he simply writes 460, then puts the decimal point between the first two digits (4.60) and multiplies by the proper number of "tens" to make the number as large as it actually is (460×10^5).

How can we express the measurement 0.0000549, showing only three significant figures? Write 549 and then put a decimal between the first and second digit (5.49). Finally, we would divide by the proper number of "tens" (5.49×10^{-5}). Write the following measurements using scientific notation. (You may have to round off to the correct place first.)

(1) 1028 ± 1.35 cm

(2) 10,000 ± 12 miles

(3) 0.0258 ± 0.013

(4) 0.000018 ± 0.000002

(5) 1.25 ± 0.01

II.26 - BACK TO THE SCALENE TRIANGLE

By now you probably realize some of the inadequacies of significant figures. One that is very apparent is the lack of a range of uncertainty. When measurements are expressed using scientific notation, we are never certain about the range of the uncertainty. Nevertheless, significant figures are very useful in communicating the place of the uncertainty, and knowing the place of the uncertainty is usually satisfactory.

Refer back to the data you collected when you tried to calculate the area of the scalene triangle. Refer back to the section on instrumental and human error and error due to changes within the system. Assign a range of uncertainty to each of your measurements, then round them off to the proper place. Now express them using scientific notation. Finally, recalculate the area of the triangle from the three sets of bases and heights using only significant figures. Are those digits that are certain the same in all three cases? If there is some variance in the uncertain place, is this understandable? Remember, significant figures are all the certain digits plus one more.

Exercises for Home, Desk and Lab (HDL)

(1) Observation is made of a burning candle. Which of the following can be considered quantitative descriptions?

(a) The candle gives off light and heat as it burns.

(b) The top of the candle becomes wet with a colorless liquid.

(c) The wick is made of strands of string which are 9.8 cm long.

(d) The candle becomes shorter at a rate of 1 cm/minute.

(e) The top of the candle becomes bowl-shaped.

(2) A student designs his own system of measurement. Using his system, he measures his height and a friend's height. He finds the ratio of his height to his friend's is 1.2/1.0. His friend argues that the ratio would be different if they used the metric system. Is the friend correct? Why?

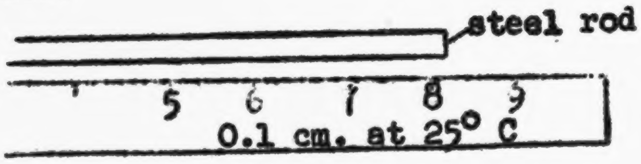
(3) If you multiply distance times distance times distance, what are the dimensions of your answer? (Use D for

distance, M for mass and T for time.)

(4) What are the dimensions associated with the speed of your family car? (Use D for distance, M for mass and T for time.)

(5) If you multiply mass times distance per time squared, then multiply by distance, what are the dimensions of your answer? (Notice the similarity to the expression for E_k.)

(6) A steel rod has to be measured. The picture drawn below is what you see while making the measurement. The steel rod is at room temperature and so is the ruler.



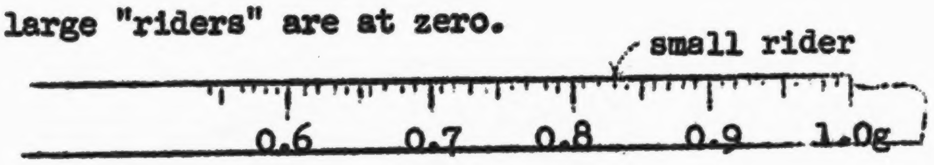
(a) What uncertainty would you associate with the measurement?

(b) Write the measurement with the total uncertainty.

(c) What is the range of the uncertainty?

(7) A student sees the following while making a measurement using a typical

triple-beam centigram balance. The large "riders" are at zero.



(a) What human error would you associate with this measurement?

(b) What instrumental error would you associate with this measurement?

(c) Assuming the error due to change in the system is zero, what total uncertainty would you associate with the measurement?

(8) What is the range of the uncertainty in the measurement 6.2 ± 0.2 grams?

(9) What is the range of the uncertainty in the measurement 100.02 ± 0.08 seconds?

(10) What is the place of the uncertainty in the measurement 6.02 ± 0.2 grams?

(11) What is the place of the uncertainty in the measurement 100.02 ± 0.08 seconds?

(12) Round the following off to the correct place:

(a) 1.065 ± 0.0295

(b) 0.0059 ± 0.005

(c) 1649 ± 100

(13) Express the following using significant figures:

(a) 649.2 ± 0.5

(b) 0.00059 ± 0.00015

(c) 5649 ± 29.5

(14) Add the following and express your answer using scientific notation:

(a) 649.2 ± 0.5
29.26 ± 0.01
1.269 ± 0.001

(b) 527.8 ± 0.1
61.39 ± 0.01
---

(15) Subtract the following, expressing your answers in scientific notation:

(a) 32.50 ± 0.01
- 8.902 ± 0.001

(b) 657.89 ± 0.06
549.01 ± 0.01
---

(16) Multiply the following, expressing your answers in scientific notation:

(a) $\begin{array}{r} 156 \pm 2 \\ \underline{365 \pm 6} \end{array}$ (b) $\begin{array}{c} 1.009 \pm 0.001 \\ \underline{\quad 2 \pm 1 \quad} \end{array}$

(17) Divide the following, expressing your answers in scientific notation:

(a) $\dfrac{654.298 \quad 0.001}{2.0 \quad 0.1} =$

(b) $\dfrac{54.07 \quad 0.05}{1.68 \quad 0.01} =$

II.27 - Experiment: MASS OF A TURTLE

You observed a turtle earlier in the course. Weight your turtle to the nearest gram and write its mass on the board. Prepare a class histogram or bar graph showing the number of turtles at a given mass on the y axis and the mass of the turtles on the x axis.

You have already determined your reaction times in Experiment I.15 and I.16. Refer to the graph of your results. Does the turtle-mass graph resemble your reaction time graph? Graphs are used to present experimental data in an easily understood fashion. In addition, the shape of the resulting curve often leads to important insights.

Distribution curves seem to be related to living systems because both of your graphs were obtained from observations on living systems--turtles and humans. Perhaps distributions also occur in non-living events and are a fundamental property of nature.

II.28 - Experiment: COIN FLIPPING

Shake ten coins in a box, remove the lid and count the heads. Record the number of heads after each shake. Repeat this operation twenty times. Graph the results by placing the number of trials with the same number of heads on the y axis and the number of heads in each trial on the x axis. Is this graph similar to the turtle-mass and human reaction time graphs? Does it appear that distributions due to random events are a general occurrence in nature?

II.29 - Demonstration: CLASSIFICATION AND ORGANIZATION

We live in a world where most objects and events have names. And names, in part at least, are a way of classifying and organizing information according to the scheme of language. What holds our attention best is something new. Our interest is immediately directed towards placing the new thing in its proper place in the world of things we already know. Often the shape and direction of your investigation of the new thing is strongly influenced by your first guess as to what it is. Thus taste and smell are used to investigate a powdered breakfast drink but not usually a powdered detergent.

In science, classification and organization of information must be done as concisely as possible. It is important not only in communicating what you have learned to other people, but also in guiding your investigation as it proceeds. The game of Twenty Questions is a good example of how one uses information logically to obtain new information and eventually to identify the object in question.

A good example of how proper organization can lead more quickly to the answer than simple guessing is provided by a deck of cards. How many "yes or no" questions do you think necessary in order to identify positively a card chosen by someone else? Certainly you could do it with fifty-two questions, but what is the minimum number of questions that would be sufficient?

You have used a flow sheet in identifying one card out of fifty-two. You have probably noticed that this system of organizing and classifying provides a useful way of dividing up the possible alternatives into smaller and smaller groups--that is, a way of going from the general to the particular. At the same time it provides a roadmap or sequence of operations which lead you most quickly to the answer.

But the flow sheet has its limitations. It is most useful only when a great deal is known in advance about the collection of things which you want to analyze--that is, when you already know what characteristics there are and which are most important or general and which are trivial.

II.30 - Experiment: CLASSIFICATION OF LEAVES

Knowing very little about the collection of objects in question, what do you do then when you have to start from "scratch"? Try it now by observing the collection of leaves provided, noting as many characteristics as you can for each leaf. A useful device in this case is the Roman Square. This is a less organized and more "open-ended" way of handling observations.

The square can be expanded as you examine new leaves and find new characteristics. But it would be wise first to study the leaves for 20 to 30 minutes to determine as many characteristics as you can, and then to try to arrange or

	CHARACTERISTIC SHAPE ⟶				VEINING ⟶			
Leaf Number	Teardrop	Heart	Blade	Round	Parallel unbranched	Network branches	Parallel branches	one main vein
1	yes	no	no	no	yes	no	no	no
2								
3								
4								
5								
6								
7								
8								

group them under major headings as in the example above. As you proceed, you may find that some characteristics--such as the presence of veins--are true of all leaves and therefore not of much value in classification. Others--such as round shape--may be too vague. In your examination you may use any of your senses except taste since some leaves contain poisonous substances. You may find that some pairs of characteristics usually go together, while others appear to be mutually exclusive. Probably the most difficult part of this study will be setting up the best characteristics. There is no easy solution to this; only trial and error can accomplish the job.

Once you are satisfied with your Roman Square, you may want to re-organize your characteristics into a flow sheet which would permit you to identify a leaf in your collection with as few "yes-no" questions as possible. Test your scheme of classification by having someone else in your group decide on a leaf which you then try to identify by means of these questions.

II.31 - Experiment: ORAL COMMUNICATION CHAIN

You have been introduced to instruments which, by extending your senses, can help you collect information. You have been introduced to two methods of organizing that gathered data into useful categories. Suppose you performed a laboratory experiment to find an answer to a question. How would you communicate the results you obtained to others interested in the same question? Would you keep a record of all your observations in your head until someone asked for your findings? Some people pride themselves on their good memories. Do you? You will perform a brief experiment with your classmates to see whether this method of communicating ideas is a useful technique for the scientist.

II.32 - Exercise: COMMUNICATING IDEAS

The purpose of this exercise is for you to write a description of one object in a group of objects in such a way that a reader can identify the object from your description.

Your team will be given a box containing ten small objects. Each of you is to examine all of them, then to choose one object and examine it more carefully (try not to let any of the students at the other tables see what you are handling). Now write down a description of this object using the face of the envelope handed to you for this purpose. Return the object to the box.

When each member on your team has finished, pass all your envelopes and the box of objects to the team your teacher designates.

Your table will then receive a pack of six envelopes with descriptions written on them, plus a box of objects from another table. Take one envelope apiece and try to match up the corresponding object. When you think you have the right one, place it inside the envelope, put all six filled envelopes together and take them back to the table that passed them to you.

Your table will get back its envelopes, also filled. Check them and tally up the number of correct identifications.

II.33 - OBSERVING A SYSTEM AS A SCIENTIST

When you conduct a laboratory experiment on a living thing, you have the advantage of being able to vary one condition in the environment in order to see how this change will affect the behavior of the organism. When you try to observe this organism in the field (its natural habitat), you may be able to learn more about its normal behavior. Here, however, you cannot regulate the conditions for your observations. For example, you may risk losing your specimen; while it is being observed, it may wander off into the brush and disappear. It is essential that any conclusions drawn about "normal" behavior must be done on the basis of repetitive observation. This normal behavior we refer to is valuable to the laboratory experimenter and serves as his control as he proceeds to alter the environment in the lab and observes its effect, if any.

One further point is worth noting here. A series of experiments or tests you run in the lab may give you reproducibility within a narrow range. You are correct to consider the results reliable. But here again, as in the case of your depth perception tests (Exp. I.11), the results may not be valid outside the lab. Merely imposing a laboratory environment on a living thing may be enough to modify its behavior.

II.34 - Test: THE TURTLE

Refer to the list of observations you drew up in Experiment I.1. Could you add to this list if you were asked to observe a turtle again?

Once again observe the turtle which your teacher will put before you, but this time observe it as a scientist might do it. Test your new techniques, maintaining an independent written record of every feature and activity of the turtle which can be observed in one class period.

Part II:

PROPERTIES OF MATTER

- **Outline:** Properties of Matter -

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
('66 ed)				
II.7		3 periods	IPS	The Mass of Dissolved Salt
II.8			IPS	The Mass of Ice and Water
II.9			IPS	The Mass of Mixed Solutions
II.10			IPS	The Mass of Copper and Sulfur
II.11			IPS	The Mass of Gas
II.12	The Conservation of Mass		IPS	
II.13	Laws of Nature		IPS	
*	*	*	*	*
('67 ed)				
II.8		3 periods	IPS	The Mass of Dissolved Salt
II.9			IPS	The Mass of Ice and Water
II.10			IPS	The Mass of Mixed Solutions
II.11			IPS	The Mass of Copper and Sulfur
II.12			IPS	The Mass of Gas
II.13	The Conservation of Mass			
II.14	Laws of Nature			

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
III	Characteristic Properties	20 periods	IPS	
III.1	Density		IPS	
III.2			IPS	The Density of Solids
III.3			IPS	The Density of Liquids
III.4			IPS	The Density of a Gas
III.4a			SG	Weights and Densities of Equal Volumes of Gases
III.5	The Range of Density		IPS	
III.6			IPS	Thermal Expansion of Solids
III.7			IPS	Demonstration: Thermal Expansion of Liquids
III.8			IPS	Demonstration: Thermal Expansion of Gases
III.9			IPS	Demonstration: Elasticity of Solids
III.10			IPS	Demonstration: Elasticity of Gases
III.11			IPS	Freezing and Melting
III.11a			SG	Behavior of Solids on Warming
III.11b			SG	Freezing and Melting Curves
III.12			IPS	Micro-Melting Point

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
III.13			IPS	Boiling Point
('66 ed)				
IV	Solubility and Solvents	14 periods	IPS	
IV.1			IPS	Solubility
IV.1a			SG	Temperature Versus Solubility
IV.1b			SG	The Effect of Temperature on Solubility
IV.1c			SG	The Effect of Temperature on Solubility
IV.2	Wood Alcohol and Grain Alcohol		IPS	
IV.3			IPS	Methanol as a Solvent
IV.4			IPS	Preparation of Oil of Vitriol
IV.5			IPS	Two Gases
IV.5a			SG	Two Gases
IV.6	Hydrogen		IPS	
IV.7	Carbon Dioxide		IPS	
IV.8			IPS	Testing Some Unknown Gases

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
IV.8a			SG	The Gaseous Products of a Burning Candle
IV.9	The Solubility of Gases		IPS	
IV.10			IPS	The Solubility of Ammonia Gas
IV.12	A More Careful Look at the Distillation of Wood		IPS	
*	*	*	*	*
('67 ed)				
IV	Solubility and Solvents	14 periods	IPS	
IV.1			IPS	Solubility
IV.2			IPS	The Effect of Temperature on Solubility
IV.1a & IV.2a			SG	Temperature Versus Solubility
IV.2b			SG	The Effect of Temperature on Solubility
IV.2c			SG	The Effect of Temperature on Solubility
IV.3	Wood Alcohol and Grain Alcohol		IPS	

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
IV.4			IPS	Methanol as a Solvent
IV.5			IPS	Preparation of Oil of Vitriol
IV.6			IPS	Two Gases
IV.6a			SG	Two Gases
IV.7	Hydrogen		IPS	
IV.8	Carbon Dioxide		IPS	
IV.8a			SG	The Gaseous Products of a Burning Candle
IV.9	The Solubility of Gases		IPS	
IV.10			IPS	The Solubility of Ammonia Gas
IV.11	Other Solvents		IPS	
IV.12	A More Careful Look at the Distillation of Wood		IPS	
*	*	*	*	*
('66 ed)				
V	The Separation of Substances	23 periods	IPS	
V.1			IPS	Fractional Distillation
V.1a			SG	Fractional Distillation

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
V.2	Petroleum		IPS	
V.3	The Direct Separation of a Mixture of Solids		IPS	
V.4a			SG	Separation of a Mixture of Solids
V.5			IPS	Fractional Crystallization
V.5a			SG	Fractional Crystallization
V.6			IPS	The Substances in a Sample of Black Ink
V.7			IPS	Paper Chromatography
V.7a			SG	Paper Chromatography
V.8	Mixtures of Gases		IPS	
V.9			IPS	Separating a Gas from Air
V.9a			SG	Separating a Gas from Air
V.10			IPS	Another Component of Air
V.11	Nitrogen and Oxygen		IPS	
V.12	Low Temperatures		IPS	
V.13	The Fractional Distillation of Air		IPS	
V.14	Mixtures and Pure Substances		IPS	

SECTION ('67 ed)	TOPIC	TIME	TEXT	EXPERIMENT
V	The Separation of Substances	23 periods	IPS	
V.1			IPS	Fractional Distillation
V.1a			SG	Fractional Distillation
V.2	Petroleum		IPS	
V.3	The Direct Separation of Solids from Liquids		IPS	
V.4			IPS	Separation of a Mixture of Solids
V.4a			SG	Separation of a Mixture of Solids
V.5			IPS	Fractional Crystallization
V.5a			SG	Fractional Crystallization
V.6			IPS	The Substances in a Sample of Black Ink
V.7			IPS	Paper Chromatography
V.7a			SG	Paper Chromatography
V.8	Mixtures of Gases: Nitrogen and Oxygen		IPS	
V.9	Low Temperatures		IPS	
V.10	Mixtures and Pure Substances		IPS	

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
VI	Compounds and Elements	18 periods	IPS	
VI.1			IPS	Decomposition of Sodium Chlorate
VI.1a			SG	Decomposition of Potassium Chlorate
VI.2			IPS	Decomposition of Water
VI.2a			SG	Decomposition of Dilute Salt Solutions
VI.3	The Synthesis of Water		IPS	
VI.4			IPS	Synthesis of Zinc Chloride
VI.4a			SG	Synthesis of a Chloride
VI.5	The Law of Constant Proportions		IPS	
VI.6			IPS	A Reaction with Copper
VI.6a			SG	A Reaction with Magnesium
VI.7			IPS	Reduction of Copper Oxide
VI.7a			SG	Oxidation-Reduction
VI.8	Elements		IPS	
VI.9	Two Special Cases: Lime and Oxymuriatic Acid		IPS	

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
VI.10			IPS	Flame Tests of Some Elements
VI.11			IPS	Spectra of Some Elements
VI.12	Spectral Analysis		IPS	

- Chapter II ('66 ed): Mass -

II.7 - Experiment: THE MASS OF DISSOLVED SALT

II.8 - Experiment: THE MASS OF ICE AND WATER

II.9 - Experiment: THE MASS OF MIXED SOLUTIONS

II.10 - Experiment: THE MASS OF COPPER AND SULFUR

II.11 - Experiment: THE MASS OF GAS

II.12 - THE CONSERVATION OF MASS

II.13 - LAWS OF NATURE

* * *

- Chapter II ('67 ed): Mass -

II.8 - Experiment: THE MASS OF DISSOLVED SALT

II.9 - Experiment: THE MASS OF ICE AND WATER

II.10 - Experiment: THE MASS OF MIXED SOLUTIONS

II.11 - Experiment: THE MASS OF COPPER AND SULFUR

II.12 - Experiment: THE MASS OF GAS

II.13 - THE CONSERVATION OF MASS

II.14 - LAWS OF NATURE

Chapter III (IPS): Characteristic Properties

III.1 - Density

III.2 - Experiment: THE DENSITY OF SOLIDS

III.3 - Experiment: THE DENSITY OF LIQUIDS

III.4 - Experiment: THE DENSITY OF A GAS

III.4a - Experiment: WEIGHTS AND DENSITIES OF EQUAL VOLUMES OF GASES

We have seen in IPS 3.4 that the gas we used did in fact have mass; therefore, we were able to establish its density.

In this experiment you will have the opportunity to attempt to weigh equal volumes of different gases -- i.e., oxygen, carbon dioxide, natural gas and perhaps other gases if available. From the accumulated information, you will then be able to compare the relative densities of these gases.

Obtain a one-hole stopper and cut a deep groove around it as shown in the accompanying diagram.

Remove the rubber cap from a medicine dropper and carefully insert the tapered end through the large end of the rubber stopper until it is completely through the stopper. Place the end of a plastic bag over the large end of the single-hole rubber stopper and secure it in place with a rubber band. Press out all of the air in the plastic bag and replace the rubber cap on the tapered end of the medicine dropper. Weigh this assembly and record.

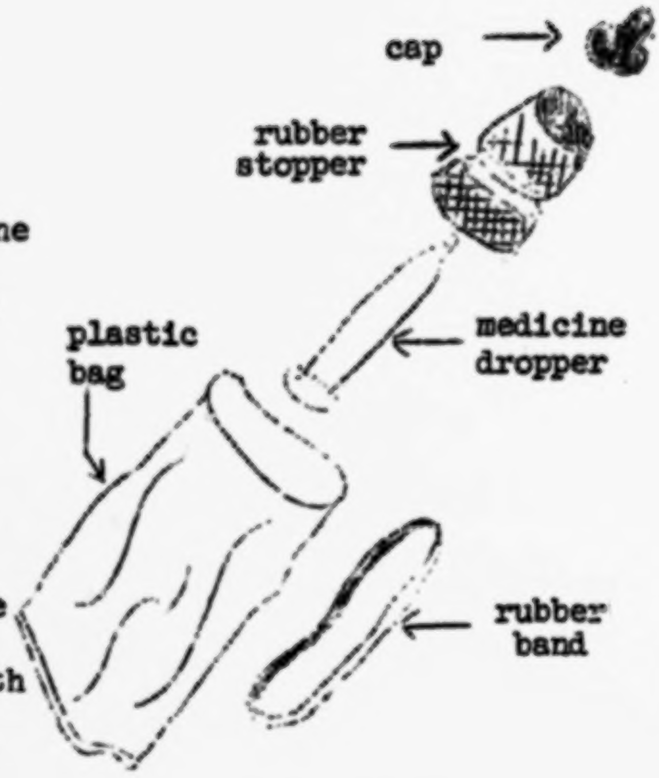


FIG. III.1

Remove the rubber cap and connect the assembly to an oxygen gas source as supplied by your teacher. Hold the bag assembly by the rubber stopper and fully inflate the bag. Let the excess gas escape so that the gas pressure inside the bag equals the atmospheric pressure, then replace the rubber cap on the medicine dropper. Weigh the bag of gas and record.

Repeat the above procedure using carbon dioxide, natural gas or any other gas that may be available to you, and record the weights for each.

To determine the volume of the plastic bag, completely fill a large bottle with water and arrange as shown in the accompanying diagram.

Remove the cap from the medicine dropper as before and attach in its place a piece of rubber tubing. Put the other end of the hose into the neck of the bottle and gently squeeze the bag until all of the air or gas used is removed. After removing the tube from the inverted bottle, place a solid stopper in the jug, remove the jug and place it upright on the table. Determine the volume of water remaining in the jug. The difference between this volume and the total volume of the jug will represent the volume of the plastic bag.

Having determined both the weights and the volumes of the respective gases, you

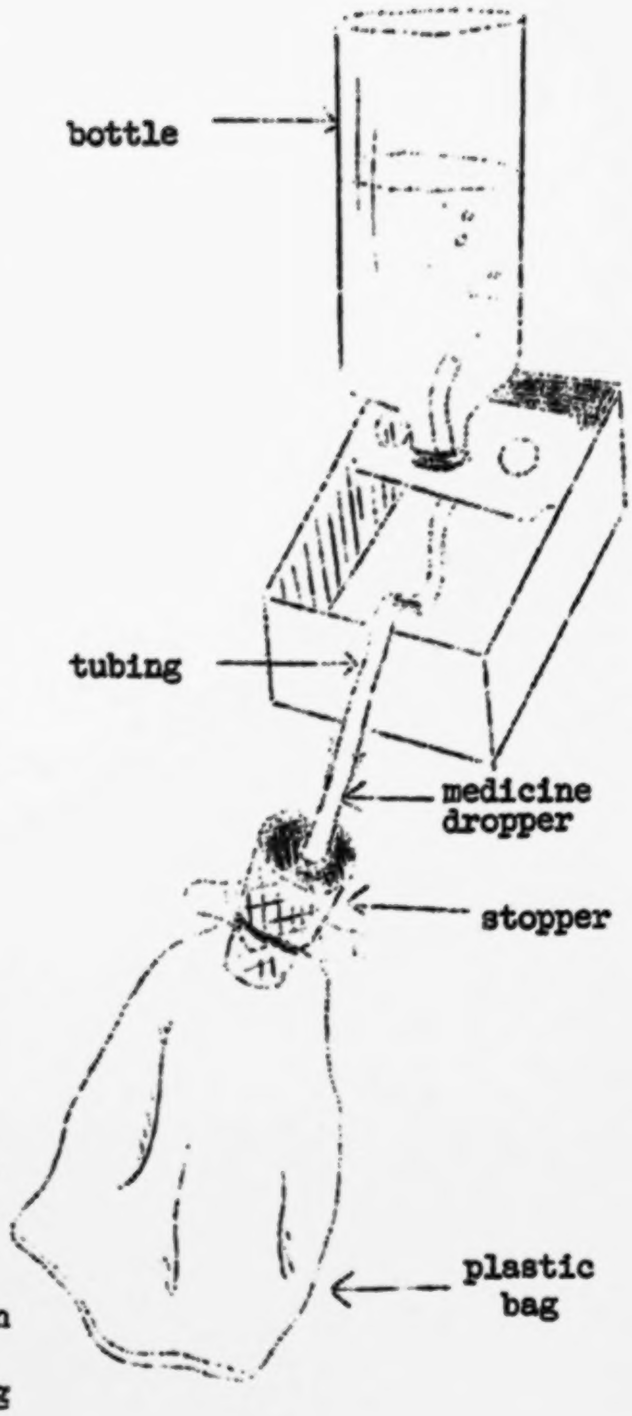


FIG. III.2

now can calculate the respective densities of these gases. Record this information and arrange these gases in the order of their increasing densities.

This experiment was performed at room temperature and atmospheric pressure. What would be your prediction of the outcome of this experiment if it had been carried out on top of Mt. Hood instead of here in the school laboratory? For example, would your data have been affected in any way and would the resulting densities of your gas samples be changed in any way? Explain the reasoning for forming your prediction.

III.5 - THE RANGE OF DENSITY

III.6 - Experiment: THERMAL EXPANSION OF SOLIDS

III.7 - THERMAL EXPANSION OF LIQUIDS

III.8 - THERMAL EXPANSION OF GASES

III.9 - ELASTICITY OF SOLIDS

III 10 - ELASTICITY OF GASES

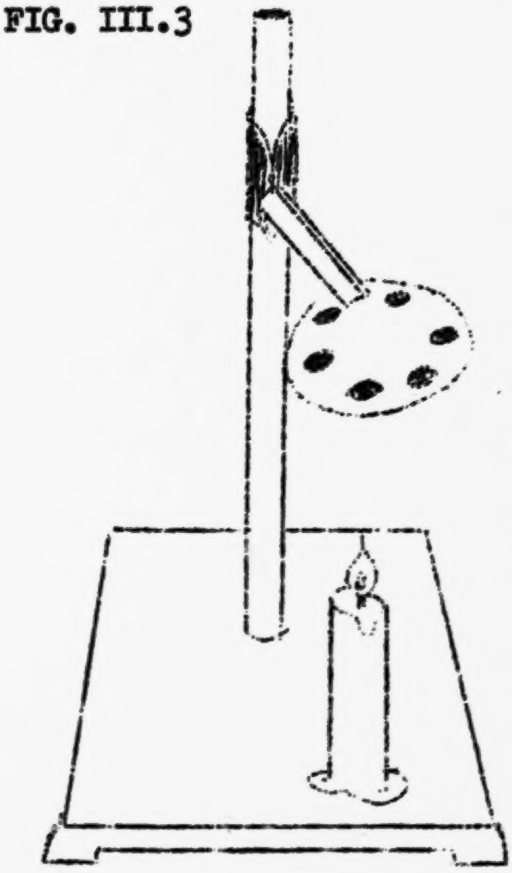
III.11 - Experiment: FREEZING AND MELTING

III.11a - Experiment: BEHAVIOR OF SOLIDS ON WARMING

Careful observation of familiar objects around us usually reveals characteristics and properties that were not obvious to us before. In this experiment you will compare the behavior of several solids when heated.

Place a lid from a tin can on an iron ring stand as shown in the figure at the right. The lid should have some depression made in it to hold the substances to be tested. Adjust the height of the ring so that it is about 8 cm above the tip of your candle. Place on the lid, equally spaced near the edge, small equal volumes of candle wax, steel wool, sulfur, lead, tin and copper wire or turnings

FIG. III.3



Light your candle and adjust the ring height until the tip of the flame is about 4 cm directly below the center of the lid. Heat the lid for about three minutes. Record your observations paying particular attention to the melting process. Replace the candle with a bunsen burner. Adjust the burner flame to about 5 cm and heat for about 3 minutes. Increase the size of the flame and heat for another 2 minutes. Record all observations.

In the burning of a candle you will observe that there is a pool of liquid at the base of the candle wick.

The question then arises as to whether the solidified liquid from the bowl of the candle will behave in the same way as the original candle wax when heated.

Remove your tin can lid from the ring stand and replace it with a wire gauze and a 250 ml beaker about 1/3 full of water. Pour a few drops of the liquid from the bowl of the burning candle onto a piece of paper. Break off a piece of the solid formed and place it in the beaker of cold water. Obtain a piece of the unmelted candle wax by cutting a chip out of the bottom of your candle. Both pieces should be about the same size. Place the second piece in the beaker apart from the first piece.

Heat the beaker and its contents with the bunsen burner and note when each substances starts to melt. Allow the beaker and its contents to cool and discard the solid material. (Do not put it in the sink.)

How does your observed order of melting compare with the findings of other members of your class? Make a generalization based on the combined observation of the class. What statement can you make concerning the melted material in the bowl of your burning candle and the candle wax? Can you make any statements as to why the substances on the tin can lid began to melt at different temperatures?

III 11b - Experiment: FREEZING AND MELTING CURVES

In experiment III.11 we attempted to show whether the freezing point was really a characteristic property of matter. We then assumed that if this was true, it would also be true that the melting point of a substance is also a characteristic property of matter. In this experiment we attempt to show that both these statements are true by studying the cooling curve of a liquid substance through its freezing point and then to study the warming curve of the same substance as it passes from its solid state through the freezing point into the liquid state.

In a clean, dry test tube place 10 grams of paradichlorobenzene and immerse in a water bath and warm gently until the substance in the test tube is completely melted. Continue heating until the temperature reaches about 70° C. Remove the test tube from the hot water bath and place in a beaker of cold water at about 30° C. Measure and record the temperature of the melted substance every 30 seconds as it cools and begins to solidify. Continue to take data for about another 5 minutes. Note when the solidifying process starts and when it ends.

Using an entire sheet of graph paper, record your data in graphical form, plotting the temperature as a function of time. (Enter the time on the horizontal axis and the temperature on the vertical axis.)

Heat a large beaker of water about 70° C. Read and record the temperature of the solid substance in the test tube and place it in the beaker of hot water. Record temperatures every thirty seconds noting when the melting begins and when it ends. (Note it may be necessary to warm up the water bath as the action continues.) Record the observed data and plot the data on the same graph used for the first part of the experiment. With a black pencil draw a smooth curve to represent the cooling behavior of the substance checked, and with a pencil of another color draw a smooth curve representing the warming behavior of the substance.

Obtain other samples of different materials from your instructor and determine the cooling and warming curves for these using the same techniques that you have used previously. Note and discuss any differences that may appear in the different substances.

Is there any significance to the fact that one or more of the substances investigated may have little or no plateau, while others may present a relatively longer plateau as they are plotted on the graph? Explain the reasoning for the choice you make.

Do you think that there would be any marked changes in either the cooling curve or the warming curve if you were to vary the number of grams of material used in each case? Explain your choice.

III.12 - Experiment: MICRO MELTING POINT

III.13 - Experiment: BOILING POINT

Chapter IV (IPS): Solubility and Solvents

The section number(s) in brackets refer to the material for this section which, when it occurs in both editions, is numbered according to the '67 ed. numbering system.

IV. 1 - Experiment: SOLUBILITY

IV. 1a (IV. 1a and IV. 2a) - Experiment: TEMPERATURE VERSUS SOLUBILITY

* * *

Chapter IV (IPS): Solubility and Solvents

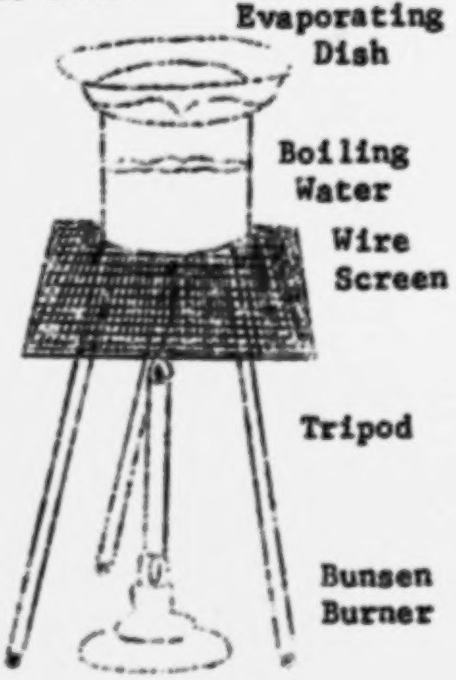
IV. 1 - Experiment: SOLUBILITY

IV. 2 - Experiment: THE EFFECT OF TEMPERATURE ON SOLUBILITY

IV. 1a and IV. 2a - Experiment: TEMPERATURE VERSUS SOLUBILITY

In this experiment, a saturated solution at a given temperature is

FIG. IV.1



evaporated to dryness. From the weight of the residue, the solubility in grams per 100 g of water can be calculated. Others in the class may be performing the same experiment at different temperatures. Share your data. You will need the solubility of a substance at many different temperatures to make a graph of solubility as a function of temperature. Such a graph is called a solubility curve.

Make several saturated solutions of potassium dichromate at temperatures ranging from 5° C to 90° C. Pour 100 ml of one of the saturated solutions into a clean, dry evaporating dish. Carefully evaporate the solvent. Let the evaporating dish cool and then re-weigh it. Repeat this process until constant weighings are obtained.

Now pour 100 ml of another saturated solution at a different temperature into a clean, dry evaporating dish and drive off the solvent. Continue using saturated solutions at different temperatures until you and your fellow students have enough data for at least five points on your graph. After you have made your graph, carefully discard the residue and wash the evaporating dishes and your hands. Potassium dichromate is poisonous.

Can you predict from your graph the solubility of potassium dichromate at a temperature you did not use? How many grams of potassium dichromate will dissolve in 1 ml of water at 60° C? Can you assume the same sort of graph is typical of the solubilities of all substances?

If you have additional time, your teacher will show you how to use The Handbook of Chemistry and Physics to make solubility curves for other substances.

('66 ed.)
IV. 1b (IV. 2b) - Experiment: THE EFFECT OF TEMPERATURE ON SOLUBILITY

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('67 ed.)
IV. 2b Experiment: THE EFFECT OF TEMPERATURE ON SOLUBILITY

In previous experiments, the substances you work with were more soluble in hot water than in cool water. In other words, the solubility increased with an increase in temperature.

Prepare 100 ml of a saturated solution of calcium acetate at room temperature. Now heat the solution carefully. Do not let it boil. Do you think the solubility of calcium acetate increased with an increase in temperature? Could you make a solubility curve for calcium acetate? If you have time, do so, and note how it compares with the solubility curves you have already studied.

('66 ed.)
IV. 1c (IV. 2c) - Experiment: THE EFFECT OF TEMPERATURE ON SOLUBILITY

* * *

('67 ed.)
IV. 2c - Experiment: THE EFFECT OF TEMPERATURE ON SOLUBILITY

In previous experiments, the majority of the substances you worked with were more soluble in hot water than in cold water. In the case of calcium acetate, however, you discovered the solubility decreased with increasing temperature. Now let's investigate a "real strange one." Determine the solubility of sodium sulfate over a range of temperatures, 10° C to 80° C. Make a graph of your data. Use The Handbook of Chemistry and Physics and try to explain your graph.

('66 ed.)
IV. 2 - WOOD ALCOHOL AND GRAIN ALCOHOL

IV. 3 - Experiment: METHANOL AS A SOLVENT

IV. 4 - Experiment: PREPARATION OF OIL OF VITRIOL

IV. 5 - Experiment: TWO GASES

IV. 5a (IV.6a) - Experiment: TWO GASES

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('67 ed.)
IV. 3 - WOOD ALCOHOL AND GRAIN ALCOHOL

IV. 4 - Experiment: METHANOL AS A SOLVENT

IV. 5 - Experiment: PREPARATION OF OIL OF VITRIOL

IV. 6 - Experiment: TWO GASES

IV. 6a - Experiment: TWO GASES

Different gases are produced when magnesium and magnesium carbonate are added to sulfuric acid. Are the same gases produced when magnesium and magnesium carbonate are added to hyrdrochloric acid? Use the same apparatus you used in Experiment III. 4 of your IPS book. Use about half a test tube of the hydrochloric acid and five 6.5 cm lengths of magnesium ribbon to produce several test tubes of gas. You should discard the gas collected in the first test tube. Why? Test the gas to determine whether it is hydrogen. Test the gas to determine whether it is carbon dioxide. Is the gas more dense or less dense than air?

Repeat the experiment using magnesium carbonate instead of magnesium.

('66 ed.)
IV. 6 - HYDROGEN

IV. 7 - CARBON DIOXIDE

IV. 8 - Experiment: TESTING SOME
UNKNOWN GASES

IV. 8a - Experiement: THE GASEOUS
PRODUCTS OF A BURNING CANDLE

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('67 ed.)

IV. 7 - HYDROGEN

IV. 8 - CARBON DIOXIDE

IV. 8a - Experiment: THE GASEOUS PRODUCTS, OF A BURNING CANDLE

Can we use our present knowledge to help us determine some of the gases produced by a burning candle?

Invert a large (1000 ml) beaker or jar over a burning candle and leave it there until the candle is extinguished. Test the thin liquid film with a strip of cobalt chloride test paper. Moisten a second strip of cobalt chloride test paper with a drop of tap water. What conclusions can be drawn from this test? Does the evidence eliminate the possibility that something other than water caused the observed change in the test paper? Why? If the liquid film is water, where does it come from? Would you expect water to be produced if an electric heater were used in place of the candle under the beaker? Why? (You may want to try this at home.)

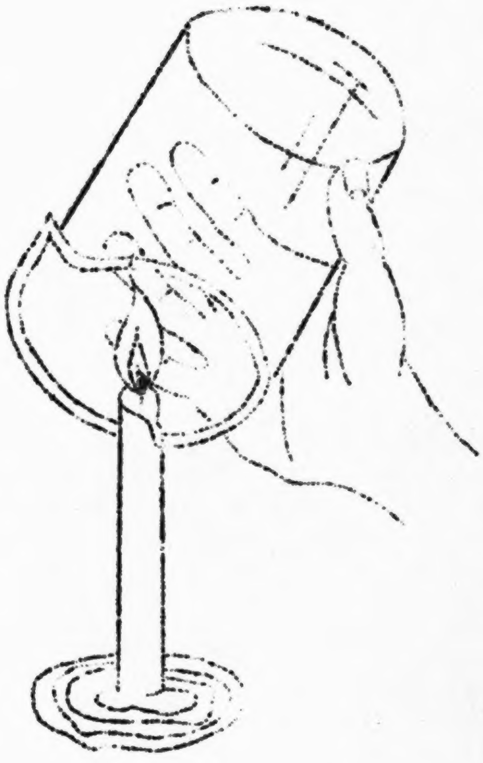

FIG. IV.2

Determine the length of time a candle

continued to burn when a quart jar is inverted over it. Next, relight the candle and use a pint jar in place of the quart jar. How do the times compare? Obviously the candle goes out in both cases. What causes it to go out? Here are two possible answers:

(a) The burning produces a gas which "quenches" the flame.

(2) The burning consumes a gas which is present in air. When this part of air is gone, the candle goes out.

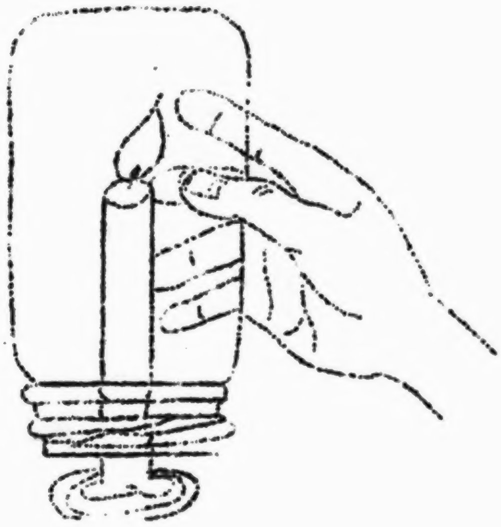

FIG. IV.3

Perhaps we can do some further experiments to help us decide if (a) or (b) or both is correct. Use a blowpipe to add air to a candle flame. Blow air from your mouth through the blowpipe into the flame until you produce a jet of flame. What does this tell you about the relative amount of carbon dioxide in your breath? Does this part of the experment tend to prove or disprove either of the given possible answers (a) or (b)? Why?

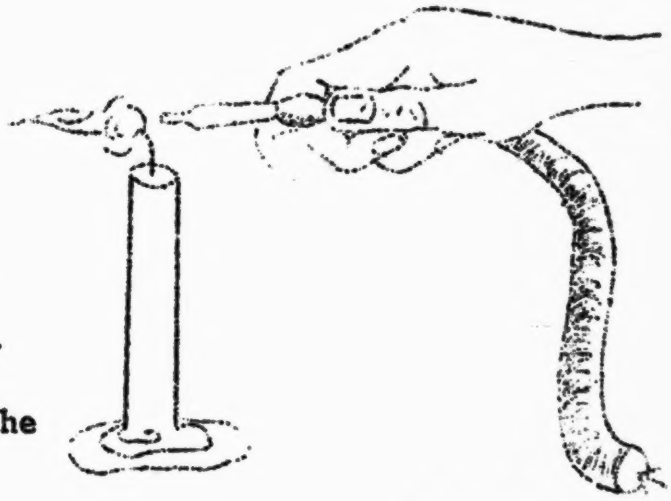

FIG. IV.4

Invert a 250 ml Erlenmeyer flask over a burning candle. When the flame goes out, quickly place the flask right side up on the table. Use a second 250 ml Erlenmeyer flask as a control. Add about 25 ml of limewater solution to each flask. Swirl the solution in each flask until a change takes place in one of the flasks. Does this part of the experiment tend to prove or disprove either of the given answers (a) or (b)? Why? Name some possible products when the candle burns as indicated by this experiment. If you are interested in further study of the properties of a burning candle, refer to Appendix 6, Experiment 4a of the CHEM Study Laboratory Manual. Your teacher probably has a copy of the manual at his disposal.

IV. 9 - THE SOLUBILITY OF GASES

IV. 10 - Experiment: THE SOLUBILITY OF AMMONIA GAS

IV. 11 - OTHER SOLVENTS

IV. 12 - A MORE CAREFUL LOOK AT THE DISTILLATION OF WOOD

Chapter V (IPS): Separation of Substances

V.1 - Experiment: FRACTIONAL DISTILLATION

V.1a- Experiment: FRACTIONAL DISTILLATION

In V.1 we found some liquids were mixtures even though they appeared to be just one substance. We also used a few of the methods used by the scientist to separate the components of the mixture. But we should not assume these will work in all cases. Sometimes we have to work out new techniques with the approval of your teacher when those we have used in the past do not fit our present needs.

Your teacher will supply you with a mixture that you are to separate. First try fractional distillation. If necessary, try other methods with the approval of your teacher.

V.2 - PETROLEUM

V.3 - THE DIRECT SEPARATION OF SOLIDS FROM LIQUIDS

V.4 - THE SEPARATION OF A MIXTURE OF SOLIDS

V.4a - Experiment: SEPARATION OF A MIXTURE OF SOLIDS

In V.1a we separated various liquids from each other but could we separate solids from each other by the same method? We know some stains we get on our clothes can be washed out with water while others require cleaning solvent. If we examine our sample carefully, we find it very hard to see any visible difference between the crystals. Does the odor give you an indication as to what at least one of the substances might be?

Mix your sample with some water and filter. Wash the residue twice and set aside with the filter paper to dry on a paper towel. Evaporate the filtrate to dryness and compare the filtrate crystals to the residue crystals. Are they the same? Could they possibly be the same?

V.5 - Experiment: FRACTIONAL CRYSTALLIZATION

V.5a - Experiment: FRACTIONAL CRYSTALLIZATION

Examine the sample supplied by your teacher. How many different types of solids can you observe?

V.5a - Experiment: FRACTIONAL CRYSTALLIZATION

Examine the sample supplied by your teacher. How many different types of solids can you observe?

Place your sample in a beaker and add a small amount of water. Heat the mixture until boiling begins. As boiling continues, add water a little at a time until all the sample is dissolved. Use as little water as possible. Add a few boiling chips. Note the volume of the solution and continue boiling gently until approximately half the water is boiled away. Were there any changes you noticed during the boiling process?

Filter the solution into a clean test tube using the hot filtration method and allow the filtrate to sit overnight. The precipitate, along with the filter paper, should be placed on a paper towel and allowed to dry.

After both solids have been allowed to sit overnight, observe them carefully. Do they look alike? If not, how do they differ? Pour the liquid off the filtrate solid and dry this solid on a paper towel. Place small, equal quantities of these solids in separate test tubes and add about 2 or 3 cc of water (equal volumes) to each test tube. Observe the solubilities of each and then boil. Continue to boil until the point of saturation is reached. How do the solubilities of these two materials compare at various temperatures? What tentative conclusions can you make about these materials?

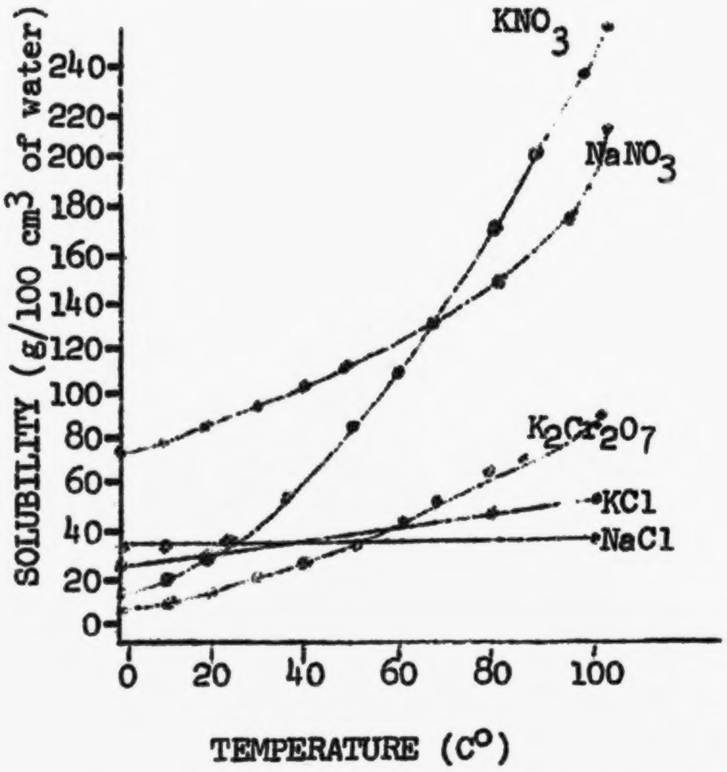

FIG. V.5a - Solubility curves of different substances dissolved in water

V.6 - Experiment: THE SUBSTANCES IN A SAMPLE OF BLACK INK

V.7 - Experiment: PAPER CHROMATOGRAPHY

V.7a - Experiment: PAPER CHROMATOGRAPHY

Many substances we use in the home and laboratory are mixtures. Some of these can be separated by paper chromatography using water as the vehicle, but some materials must have different vehicles such as alcohol or other. Why is this?

Using a graduated cylinder in the laboratory and perhaps a fruit jar or milk bottle at home, construct a paper chromatographic separation apparatus.

Is it necessary to use materials that are water soluble if the vehicle used is water, or will any material work? Why? Occasionally a separation occurs with the original color between two other colors. How can this happen?

An HDL problem at the end of this chapter suggests items in your home that can be used. Try some of these and perhaps other materials such as food coloring, and bring the dried papers (chromatograms) to class to share with your classmates.

V.8 - MIXTURES OF GASES

V.9 - Experiment: SEPARATING A GAS FROM AIR

V.9 - Experiment: SEPARATING A GAS FROM AIR

As we watch the smoke from a fire rise into the atmosphere or smell the exhaust from a bus or car, we begin to wonder about the composition of air.

Affix a strip of masking tape to the outside of each of four test tubes. Place the mouth of tube #1 down in a large beaker filled 3/4 full of water so that the mouth is beneath the surface of the water.

Insert a stopper in each of the remaining three tubes and mark the farthest extent of the stopper in the tube as mark "A". Remove the stopper in tubes 2, 3 and 4 and add 25 ml of sodium hydroxide solution to each. Replace the stopper to point A, invert the tube and mark the level of the liquid as mark "B". Turn the mouth of test tube #2 up and remove the stopper. Very quickly add 0.5 g of pyrogallic acid. Replace the stopper to point A and shake vigorously for 2-3 minutes. Do you notice any evidence of change in the tube? Place the mouth of the test tube under the surface of the water in the beaker. Repeat this process for tubes 3 and 4. Remove the stoppers from tubes 2, 3 and 4 very carefully. Wait a few minutes,

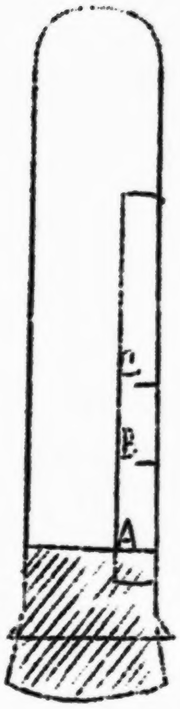

FIG. V.1

then move test tubes 2 and 3 up and down until the liquid levels inside and outside the tubes are the same. Mark the level of the liquid as mark "C". Replace the stopper in tube #2. Save tube #2 for experiment V.10.

Put your thumb over the open end of tube #1, which did not contain any sodium hydroxide or pyrogallic acid, and remove it from the water. With your thumb still over the end, turn it right side up, light a wood splint, remove your thumb, and insert the barely glowing splint into the tube. What happens? Try this test with a tube filled with air from the room. What do you conclude about the gas in the tube that was suspended over water but did not contain any chemicals? Try this same test with tube #3. Save tube #3 for further measurements.

Test tube #4 is still inverted in the beaker of water without a stopper. While keeping the mouth of the tube below the surface of the water, stir it around until any liquid remaining in the tube has the same color as the water surrounding it. To perform the limewater test, place your thumb over the mouth of the test tube, remove it from the water, turn it right side up, pour in some limewater, place your thumb over the open end and shake well. What do you conclude about the gas you have tested?

Now let us return our attention to test tube #3. Fill the tube with water up to mark C. Pour this water into a graduated cylinder and measure the volume. Measure the volume up to mark B in the same way. What does this tell you about the volume of the original gas or air that was lost?

('66 ed)

V.10 - Experiment: ANOTHER COMPONENT OF AIR

V.11 - NITROGEN AND OXYGEN

V.12 - LOW TEMPERATURES

V.13 - THE FRACTIONAL DISTILLATION OF AIR

V.14 - MIXTURES AND PURE SUBSTANCES

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V.8 - MIXTURES OF GASES: NITROGEN AND OXYGEN

V.9 - LOW TEMPERATURES

V.10 - MIXTURES AND PURE SUBSTANCES

Chapter VI (IPS): Compounds and Elements

VI.1 - Experiment: DECOMPOSITION OF SODIUM CHLORATE

CAUTION: Be sure to use the glass wool plug and a clean and dry test tube. Try to identify the gas evolved.

VI.1a - Experiment: DECOMPOSITION OF POTASSIUM CHLORATE

Weigh out about 30 beads (7 gm) of potassium chlorate and 15 beads of manganese dioxide. Mix these together on a piece of paper. Heat the mixture in a test tube as shown in Fig. 6.1 (IPS text).

CAUTION: Do not grind these chemicals together. Be sure you use the glass wool plug and do not allow the material to touch the glass wool plug while heating. If the mixture moves up the tube, tap it gently or briefly remove the heat. You must use a clean, dry test tube.

Collect several test tubes of gas. Then take the stopper out of the tube you are heating and continue to heat for 10 to 15 minutes, or until no further change is noticed. To make sure all material was heated, rotate the tube while heating but be careful not to burn your fingers.

What gas did you collect?

Was gas evolved after you stopped collecting?

How does the melting point of the material (potassium chlorate) you started with compare with the material you now have? Can you regain all of the manganese dioxide you started with? How do the solubilities of the materials compare?

Make graphs of the solubilities of the two materials. Can you make a comparison between either material and a known solubility curve?

What else can you do to identify the second material?

Did you evolve pure substances?

VI. 2 - Experiment: DECOMPOSITION OF WATER

VI. 2a - Experiment: DECOMPOSITION OF DILUTE SALT SOLUTIONS

Use the same apparatus and collecting techniques as you used in IPS Experiment 6.2. The difference lies in the solution used. IPS 6.2 used a dilute sulfuric acid solution. You will use dilute salt solutions.

To make the solutions, take 10 g of salt used and dissolve it in 200 ml of distilled water. Your teacher will indicate which of the following salts you should use.

Salts: Sodium sulfate, sodium carbonate, sodium nitrate, potassium sulfate, potassium nitrate, potassium carbonate, calcium nitrate.

What gas(es) have evolved?

How does your result compare with the results of the original IPS experiment?

If two gases evolve, try mixing and igniting the mixture. What do you conclude?

Compare your results with those using other salts. Is there a conclusion you can draw?

VI. 3 _ THE SYNTHESIS OF WATER

VI. 4 - Experiment: SYNTHESIS OF ZINC CHLORIDE

The material left in the evaporating dish should be evaporated in the following manner. Heat until the substance appears to be dry, then continue until a pool of liquid begins to form. Stop heating and weigh as soon as cool.

VI. 4a - Experiment: SYNTHESIS OF A CHLORIDE

In IPS VI. 4 you synthesized a metallic chloride. Carefully re-read this section in your IPS book since you will follow the same directions and answer the same questions. The only change will be in substituting the metal used.

Zinc was the metal you used before; now you will try the same experiment using either aluminum or magnesium. Aluminum will be supplied as foil and should be abraded to remove any surface contamination. Magnesium ribbon requires the same treatment. In both cases do this lightly so that you leave most of the metal in usable form.

If you remember the ratios that you computed for zinc-zinc chloride (or get them from your instructor), compare them with the ratios that are computed in this experiment. Do you see a pattern? If so, can you express this pattern mathematically?

Knowing that chemists write zinc chloride as $ZnCl_2$ and that the chemical symbol for zinc is Zn; for chlorine, Cl; for aluminum, Al; and for magnesium, Mg; can you write a formula for the chlorides you produce?

VI. 5 - THE LAW OF CONSTANT PROPORTIONS - Proust (1754-1826)

VI. 6 - Experiment: A REACTION WITH COPPER

Recording the time may be eliminated from this experiment.

VI. 6a - Experiment: REACTION WITH MAGNESIUM

Carefully weigh a clean, dry crucible, add 0.3 - 0.4 g magnesium ribbon cut into small pieces, and weigh again.

You should scrape or abrade the ribbon first. Why?

Put a lid on the crucible and heat it slowly, frequently lifting the lid with a pair of tongs.

What purpose does lifting the lid serve?

If the magnesium begins to burn brightly, immediately recover the crucible. Heat until all of the metal seems to have been converted to ash. Remove the cover and add a few drops of water

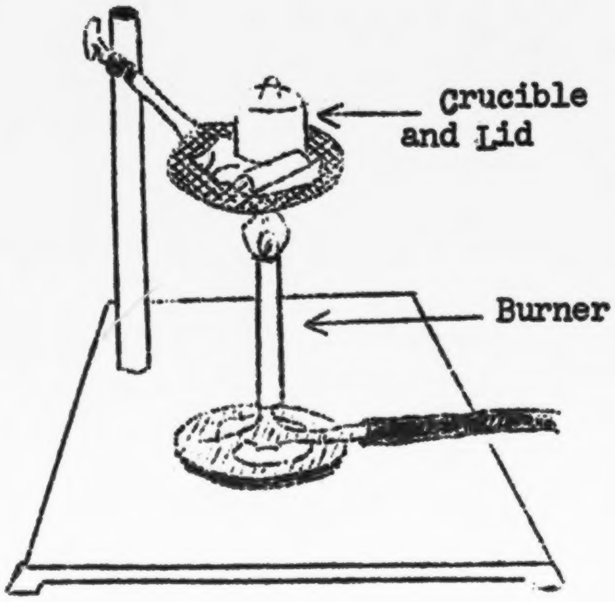

FIG. VI.1

while the crucible is still warm, gradually/ heat the crucible to the maximum degree allowed by the burner. Allow the crucible to cool, them weigh it. Again heat the crucible, cool, weigh again. If the weight changed after the last weighing, heat and weigh again until no further weight change is observed.

Is there a difference between your first weight of the crucible and ribbon and your last weight? How do you explain this?

VI. 7 - Experiment: REDUCTION OF COPPER OXIDE

The ratio of copper oxide to charcoal is 10 beads CuO to 1 bead charcoal.

You should heat the mixture until it begins to glow. Continue to heat for about 1 minute, then allow the tube to cool and proceed as directed.

VI. 7a - Experiment: OXIDATION-REDUCTION

When you did Experiments VI. 6 and VI. 7 in your IPS course work, you heated copper powder and it combined with oxygen from the air. It was thus oxidized. You then reduced the copper oxide and regained the copper you started with.

Set up a bunsen burner and look at the flame. You will find two general regions within the flame itself, the outer or apparent boundary of the flame, and an inner cone just above the barrel of the burner. Hold a strip of copper metal (don't hold it directly by hand or you will burn yourself) just above the tip of the outer region of the flame. Record the changes that take place. Now move the changed region so that the tip of the inner cone just touches it. Record any changes that occur.

The outer flame is called the oxidizing flame and the inner is called the reducing flame. In the light of this information, how would you describe what you have observed?

What difference in these regions would lead to the difference in their chemical activity?

VI. 8 - ELEMENTS

VI. 9 - TWO SPECIAL CASES: LIME AND OXYMURIATIC ACID

VI. 10 - Experiment: FLAME TESTS OF SOME ELEMENTS

VI. 11 - Experiment: SPECTRA OF SOME ELEMENTS

VI. 12 - SPECTRAL ANALYSIS